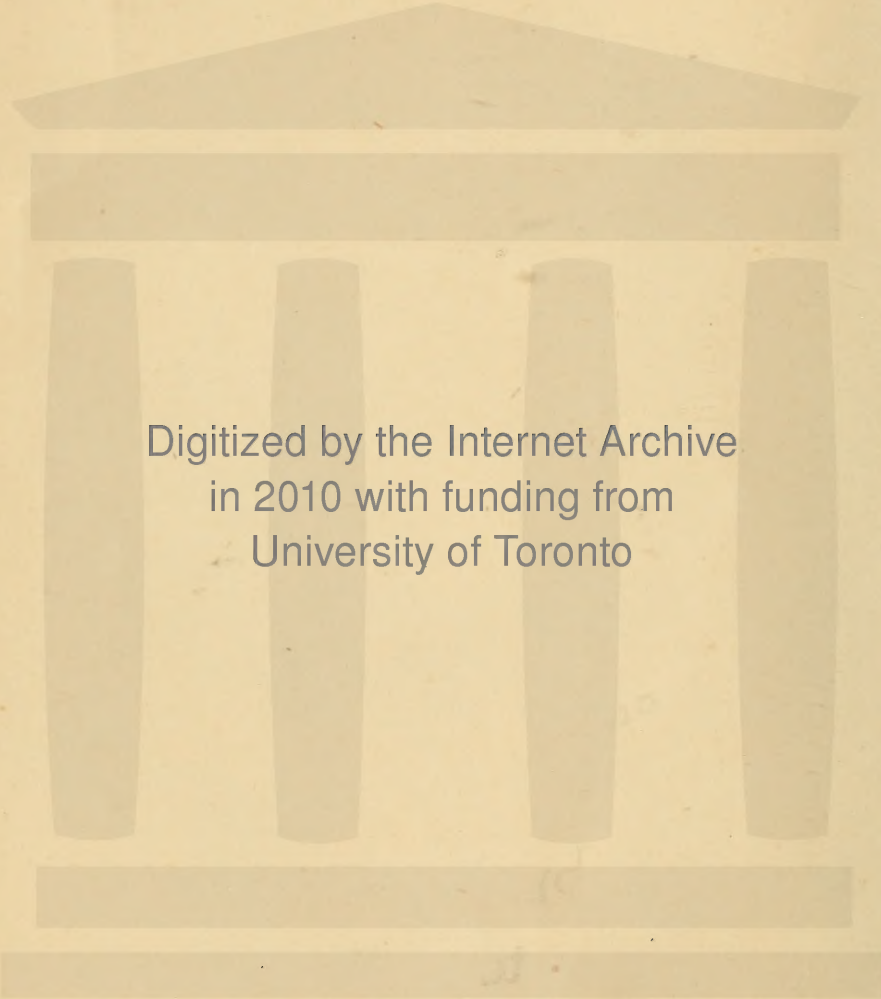


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Technical
Illuminating Engineering

(TRANSACTIONS
OF THE
ILLUMINATING ENGINEERING
SOCIETY)

VOL. XIII
JANUARY - DECEMBER
1918

Part I—Society Affairs

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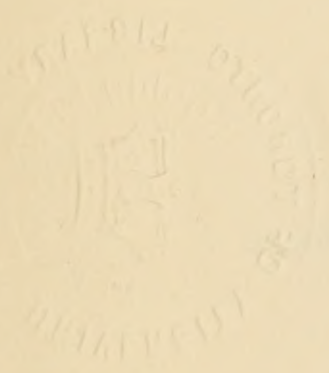
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TRANSACTIONS

OF THE

Illuminating Engineering Society

PART I -- SOCIETY AFFAIRS

VOL. XIII

FEBRUARY 11, 1918

No. 1

COUNCIL NOTES.

ITEMS OF INTEREST FROM THE COUNCIL MEETING OF JANUARY 10, 1918.

Local Representatives.

The General Secretary presented to Council a pleasing report of progress among the local representatives of the Society. At this time there are thirty-one representatives of the Society actively engaged in fostering good lighting propaganda in various sections of the country. The work so far undertaken by them includes co-operative efforts with state and municipal authorities in preparing lighting codes, the presentation of lectures on illumination, acting as delegates to certain conventions and meetings at which the Society has been asked to be represented, and in arranging meetings of civic organizations for the purpose of directing attention to good lighting principles and practice. Much good work has been accomplished in this way. Our local representatives are to be congratulated upon their work. Mention of specific meetings and other activities are made in other columns of this issue, and in preceding numbers of the TRANSACTIONS.

Transfer to Full Membership.

At this time Council is giving careful

consideration to the eligibility of associate members for transfer to the higher grade of member. Certain men of the lower grade who have practiced the science and art of lighting through several years of associate membership in the Society have attained sufficient knowledge to entitle them to be classified as experts in certain fields of illuminating engineering. Other associate members, who have been proficient in specialized branches of the art and who now have executive direction and supervision of important lighting work should also be considered for the higher grade of membership. To all who hold the grade of member, the Society has given careful and consistent attention to their qualifications before entrance or transfer. The constitutional requirements, which define the degree of technical knowledge, important contributions to the art, or period of employment in work having a direct bearing on illumination; have ensured for men who are classified as members, a professional standing that is of material importance in their business associations. It is to be hoped that some careful thought will be given by associate members to the desirability of transfer to the higher grade.

Legislation on Lighting.

Steady progress is being made by the Committee on Lighting Legislation,

through its sub-committees, in co-operating with state authorities for the preparation of lighting codes. Special mention was made at this meeting of the Council of the sub-committees working on codes in co-operation with officials of the States of Wisconsin, Ohio, Pennsylvania and New Jersey.

Annual Convention Details.

The advisability of holding an annual convention was referred to the Committee on Time and Place which was appointed at this meeting of the Council, and was requested to make its report on this subject at the Council meeting of February 14th.

New Members.

Upon recommendation of the Board of Examiners the following applicants were elected to membership:

Six Associate Members.

- BONNER, JOHN J.,
Special Factory Representative,
Welsbach Co.,
Gloucester, N. J.
- EWING, R. E.,
Designer,
Welsbach Co.,
Gloucester, N. J.
- HARTMAN, LEON WILSON,
Professor of Physics,
University of Nevada,
215 Maple, Reno, Nevada.
- GALLAGHER, FRANCIS A., JR.,
Narragansett Electric Lighting Co.,
Turks Head Building,
Providence, R. I.
- PERRY, ALLEN M.,
Technical Editor,
Electrical World,
36th Street & 10th Ave.,
New York, N. Y.

STETSER, JESSE R.,
Special Factory Representative,
Welsbach Co.,
Gloucester, N. J.

SECTION ACTIVITIES.

Attention of all members is called to the meeting of the Society to be held in New York, Feb. 14, 1918. See announcement on page facing page I of this number.

SCHEDULE OF MEETINGS

(Announced to the General Office prior to publication. Subject to revision.)

CHICAGO.

February 21—"The Lighting Art, Its Practice and Possibilities in Interiors," by M. Luckiesh.

NEW ENGLAND.

Announcement pending.

NEW YORK.

February 14—Meeting canceled to allow members to attend the meeting of the national body on this date.

PHILADELPHIA.

Announcement pending.

PITTSBURGH.

Announcement pending.

CHICAGO SECTION.

Section Meeting of January 17, 1918.

A meeting of this Section was held on the above date. Thirty-eight members and guests were in attendance. The attendance was small due to the fact that severe weather conditions and the electric club dinner and dance occurred on the same evening.

Mr. W. A. Durgin gave an illustrated lecture on "Balancing the Light Beam" with many ingeniously constructed special apparatus. Mr. Durgin demonstrated the principles of photometry.

He laid special emphasis on the inability of the eye to judge brightness values with any accuracy and of the relatively very low order of precision of all photometric measurements. The construction and use of numerous types of photometers was explained and the details were shown of the Sharp-Millar and Macbeth portable photometers, the foot-candle meter and the new relative brightness meter or comparator which is now being developed by Mr. Durgin.

The lecture was discussed by the following: Mr. E. H. Freeman, Chairman; Mr. J. R. Cravath, Mr. A. L. Arenberg, who called attention to the numerous precautions that must be taken to enhance the accuracy of all light measurements.

Mr. Durgin admitted such work is rough, but usually answered all purposes if it shows the order of intensity or brightness. He further called attention to the fact that, after all, too much stress has been laid on the comparative efficiencies of competitive lighting equipments, and not enough on their ruggedness, maintenance, ease of cleaning and other important operating features.

NEW ENGLAND.

Section Affairs.

Mr. T. H. Piser, Vice-president of this Section reports in a recent letter to the General Office, that Chairman, S. C. Rogers has returned from a protracted business trip and will now "make plans to push the affairs of this Section."

* * *

Mr. H. F. Wallace has been appointed as Chairman of the New England Section Membership Committee and, as such, is a member of the National Committee on Individual Membership.

NEW YORK.

Section Meeting of January 10, 1918.

About seventy members and guests enjoyed Mr. L. B. Marks' abstraction of the Code of Lighting School Buildings. Mr. C. B. Snyder, Superintendent of School Buildings, Department of Education, City of New York, discussed the practical application of the Code.

Among the guests were members of the National Educational Association, and others interested in school lighting problems. An enthusiastic and instructive discussion followed the presentations.

A number of the attendants dined informally at Healy's Restaurant preceding the meeting.

PHILADELPHIA.

Board Meeting of January 4, 1918.

Reports of progress from the Chairmen of the Exhibition and Papers Committees were received. The latter Committee proposed tentative programs for the February, March, April and May meetings, and were instructed to proceed with final arrangements.

Mr. R. ff. Pierce was chosen as the Section's representative on the Council to act for Dr. G. S. Crampton, during his absence in patriotic service for the Government.

Section Meeting of January 10, 1918.

A joint meeting of the Franklin Institute, the Physics Club of Philadelphia, and the Illuminating Engineering Society was held at the Franklin Institute. The meeting was opened by Dr. George A. Hoadley, Acting Secretary of the Franklin Institute, and was then turned over to Walton Forstall as Chairman of the Philadelphia Section of the Illuminating Engineering Society. The

paper of the evening was on "The Physics of the Welsbach Mantle." The lecturer was Dr. Herbert E. Ives, formerly physicist of The United Gas Improvement Company, but now Captain in the Science and Research Division of the U. S. Signal Corps, specializing on photography in relation to aviation. The lecture dealt with the nature of radiation, with special attention to selective temperature radiation. The radiation from various oxides and oxide mixtures, of which the Auer mixture of thoria and ceria is the most efficient, was discussed in detail, and the behavior of the ordinary gas mantle elucidated. The lecture was illustrated by experiments and lantern slides. The auditorium was crowded to the doors by an audience whose deep interest in the lecture was best attested by the numerous questions put to Dr. Ives when the meeting was thrown open for discussion.

COMMITTEE ACTIVITIES.

Committee on Nomenclature and Standards.

A meeting of this Committee was held on December 13th in the Engineering Societies Building.

After consideration and discussion on certain paragraphs of the 1917 Report the following revisions to this report were adopted:

Paragraph 16 of the 1917 report shall be omitted.

New Paragraph 16:

16. *Brightness* of an element of a luminous surface may be expressed in either of two ways: (a) in terms of intensity, I , (b) in terms of flux, F .

(a) Brightness in terms of the luminous intensity I (or candlepower) per unit of projected area of the surface

(candlepower brightness) corresponds to the

$$\text{defining equation } b_I = \frac{dI}{dS \cos \theta}$$

where θ is the angle between the normal to the surface and the line of sight.

(b) Brightness in terms of the flux, F , per unit area of the surface, on the assumption that the surface is a perfect diffuser; *i. e.*, that it obeys the cosine law of emission or reflection (lumen brightness) corresponds to the defining equation

$$\text{defining equation } b_F = \frac{dF}{dS} \text{ (perfect diffusion assumed).}$$

The units in which brightness is measured according to (a) and (b) differ only in numerical value. See Paragraph 17.

17. *Lambert*. L , The unit of brightness in the lumen system. The lambert is the brightness of a perfectly diffusing surface emitting or reflecting 1 lumen per square centimeter. For most purposes the millilambert, 0.001 lambert, is the preferable practical unit.

To say that the brightness of a surface as viewed from a given point is n lamberts, signifies that its brightness is the same as that of a perfectly diffusing surface emitting or reflecting n lumens per square centimeter.

In practice no surface obeys exactly the cosine law of emission or reflection; hence the brightness of a surface generally is not uniform but varies somewhat with the angle at which it is viewed. A perfectly diffusing surface emitting 1 lumen per square foot will have a brightness of 1.076 millilamberts.

The brightness expressed in candles per square centimeter may be reduced to lamberts by multiplying by $\pi = 3.14$.

Brightness expressed in candles per square inch may be reduced to lamberts by multiplying by $\pi \div 6.45 = 0.487$.

Old Paragraphs 18, 19 and 20 shall be omitted.

The following new definitions were adopted:

Types of illumination produced on a surface:—

(1) Unidirectional illumination on a surface is that produced by a single light source of relatively small dimensions. It is characterized by the fact that a small opaque object placed near the illuminated surface casts a sharp shadow.

(2) Multidirectional illumination on a surface is that produced by several separated light sources of relatively small area. It is characterized by the fact that a small opaque object placed near the illuminated surface casts several shadows.

(3) Diffused illumination is that produced either by primary or secondary light sources having dimensions relatively large with respect to the distance from the point illuminated, and scattering light in all directions. It is characterized by relative lack of shadow. Diffused illumination may be derived principally from a single direction as in the light from a skylit window, or from all directions as in the open air. Perfectly diffused illumination on a surface is shadowless.

In any practical case of illumination on a surface there is usually a mixture of the above types.

Surfaces and media modifying luminous flux:

Diffusing surfaces and media are those which break up the incident flux and distribute it more or less in accordance with the cosine law, as for example white plaster and opal glass.

Redirecting surfaces and media are those which change the direction of the luminous flux in a definite manner, as for example, a mirror or a lens.

Scattering surfaces and media are those which redirect the luminous flux

and break it up into multiplicity of separate pencils; as for example, ripple glass, reflecting or transmitting.

LOCAL REPRESENTATIVES.

Columbus, Ohio.

Professor F. C. Caldwell of The Ohio State University, local representative in this district, is chairman of a committee entrusted with the preparation of a proposed factory lighting code for the Industrial Commission of Ohio, for which provision was made some time ago.

Discussion of Proposed Ohio Factory Lighting Code at meeting of Pittsburgh Section in Cleveland, December 14, 1917.

"The code produced by this Committee follows very closely the Code of Factory Lighting of the Illuminating Engineering Society, but the appendix provided by the Ohio Committee differs from that included in the Society's code, in that the former includes a table of industrial classifications prescribing foot-candle values for a wide variety of industrial operations.

"This code was discussed at a meeting of the Pittsburgh Section held in Cleveland. In the course of the discussion Mr. S. E. Doane emphasized the importance of educating the public to talk of illumination in terms of accepted units and emphasized the value of the Ohio code in bringing about such a condition.

"President Stickney described the work of preparation of the original I. E. S. code and complimented the Ohio Committee upon the completion of its work on the State code. Commenting upon illumination intensity standards included in the Ohio code, he emphasized the need for codification of other lighting requirements including the limitations of glare and light distribution characteristic."

I. E. S. WAR NOTES.

Conservation of Coal Through Reduced Illumination.

In the bulletin issued by the Committee on Coal Conservation of the Chamber of Commerce of the United States, under date of January 4, 1918, it is pointed out that the anticipated coal shortage for the ensuing year amounts to about $2\frac{1}{2}$ pounds per capita. Steps are being taken to reduce the consumption of coal by large users. The Committee urges however the importance of small savings and the responsibility of every individual for saving his portion. Among the admonitions included in the bulletin the following of special application in connection with illumination are earnestly commended to the attention of our readers:

CONSERVE ELECTRIC LIGHT; electric current usually comes from coal. Consult your dealer as to the most economical types of lamps suitable to your conditions and fixtures. A 25-watt lamp used instead of a 40-watt lamp saves at least an ounce of coal every two hours.

TURN LIGHTS OFF WHEN NOT NEEDED; if a 25-watt lamp or an ordinary gas light is turned off, even for short intervals, the aggregate saving may easily be an ounce of coal a day for each lamp.

DISCARD CARBON FILAMENT LAMPS; substituting a 25-watt tungsten lamp for a 16-candlepower carbon filament lamp provides a better light and saves 2 or 3 ounces of coal every day.

BURN GAS IN MANTLES, NOT IN FLAT FLAME BURNERS; the old-fashioned flat-flame gas light burner uses more than twice as much gas as a mantle burner giving more light. Each mantle burner substituted for a flat-flame burner will save probably not less than an ounce of coal a day.

Honor Roll.

To the number of war service members already listed in Volume XII, No. 7 and 8 TRANSACTIONS, we give the following additional members who have

been added to the *Honor Roll* up to January 15, 1918:

Earl A. Anderson
Edward E. Ashley, Jr.
George S. Crampton
Halsey E. Crosby
H. W. Edmund
C. E. Egeler
Francis H. Gilpin
Kenneth R. Hare
S. G. Hibben
Maurice Holland
Herbert E. Ives
C. F. Lacombe
R. C. Macdonald
Carl O. Martin
F. L. Mason
Alexander Maxwell
T. Elmer Moon
George Sims Parker
Eugene Peterson
George Robins
Edwin H. Robnett
Thomas Scofield
James J. Spillan

The General Office records as of January 15, 1918, show that the Sections' contributions to the active military and naval forces of the country are as follows:

	Members in Service
Chicago	9
New England	2
New York	18
Philadelphia	7
Pittsburgh	5
Non-Section	5
Total	46

The total number of men in service (46) constitutes 3.7 per cent. of the total membership of the Society.

Dr. H. E. Ives, of The United Gas Improvement Company, Philadelphia, Pa., has entered the Science and Re-

search Division of the Signal Corps. His temporary address is 1023—16th Street, Washington, D. C.

Attention is called to the addition to the personnel of the Committee on War Service, full list of which appears in the front of this number.

Mr. P. B. Noyes, Director of Conservation, United States Fuel Administration has recently requested copies of certain I. E. S. publications for use in the special Library of the Conservation Division.

The Committee on War Service has recently completed and filed with officers of the Navy Department, designs prepared at their request for the lighting of gun shops and machine shops now under construction.

NEWS ITEMS.

"*The Smileage News*" is a new publication issued, with the full approval of the Secretary of War, by the Military Entertainment Committee of the War Department Commission on training camp activities. This diminutive paper invites the sale of "Smileage Books"—coupon books containing admission tickets to camp theatricals. One article written in Vol. I, No. 1 of the *News* is written under the headline "What Will the Soldier See?" To the illuminating engineer the answer to this question involves more than the program of Broadway shows and entertainments that are listed under this caption. It may not be out of order to bring to mind the fact that very little can be seen unless proper auditorium and stage lighting has been installed.

Mr. H. A. Hornor has recently resigned his position as electrical engineer of the New York Shipbuilding Corporation, Camden, N. J. Mr. Hornor has been connected with this company for seventeen years during which time he has greatly advanced the applications of electricity in the marine field. He is Chairman of the Marine Committee of the American Institute of Electrical Engineers and has been active in various engineering societies. He is popular as a lecturer on his own and allied subjects and has appeared before large audiences in the prominent cities of the East and Middle West. Mr. Horner has been a frequent contributor to the journals of the electrical technical societies and is author of the article on Marine Applications in the Standard Handbook for Electrical Engineers. He is now writing a series of articles appearing in *Electrical Engineering* which deal with the practical engineering features connected with the applications of electricity to the building and navigation of ships.

Mr. Gordan L. Berry, Field Secretary of the National Committee for the Prevention of Blindness has recently departed for France to undertake work as a Y. M. C. A. secretary.

OBITUARY.

Mr. Isidor Ladoff, a former member of the Pittsburgh Section, died on January 7, 1918, at the Columbia Hospital, Wilksburg, Pa.

ILLUMINATION INDEX.*Prepared by the Committee on Progress.*

An index of references to books, papers, editorials, news and abstracts on illuminating engineering and allied subjects. This index is arranged alphabetically according to the names of the reference publications. The references are then given in order of the date of publication. Important references not appearing herein should be called to the attention of the Illuminating Engineering Society, 29 W. 39th St., New York, N. Y.

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Equilibrium Temperature of a Body		1917	
Exposed to Radiation (Abstract)—	Ch. Fabry	Dec.	480
Astrophysical Journal			
The Variation with Time of the Characteristics of a Potassium Photo-Electric Cell as to Sensibility According to Wave-Length—	H. E. Ives	Nov.	241
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A Differential Spectro-Photometer—	G. A. Shook	Dec.	305
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Bulletin National Electric Light Association			
The 50-Watt Mazda B Lamp—	News Item	Nov.	800
Light Experiment at Greenwich Village Theatre—	News Item	Dec.	898
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Store Lighting—	H. T. Spaulding	Dec.	126
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Mazda C-2 Lamp and Its Application—	A. L. Powell	Dec.	33
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Research Organization—	D. R. Kennedy	Nov. 9	435
Modern Arc Lamps and Incandescent Lamps—	News Item	Dec. 7	531

Electrical ReviewThe Filiform Crystal and its Use in
the Glow Lamp—

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War-time Lighting—

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Dec. 15 1018"Lightless" Nights Decreed Twice a
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Caution as to "Lightless" Nights—

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Dec. 22 1057

The Sign-lighting Question—

Editorial

Dec. 22 1058

Interpreting the "Lightless Nights"
Order—

Editorial

Dec. 29 1103

Electrical TimesAn Acid-proof (Incandescent Lamp)
Holder—

News Item

Nov. 22 371

Electrical WorldPrivate and Public Lighting (for
streets)—

Editorial

Dec. 8 1087

Engineering Research and Publicity—

Editorial

Dec. 8 1089

Unusual Street-lighting Practice for
Small Towns—

News Item

Dec. 15 1141

Residence Lighting Rates and Energy
Consumption—

News Item

Dec. 15 1153

Cost of Arc Lighting in an Indiana
City—

News Item

Dec. 15 1154

Adapting 220-volt Circuits to 110-volt
Lamps—

J. R. Colville

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Engineering Research—

Editorial

Dec. 22 1184

The Illumination of an Athletic Field—

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Dec. 22 1200

Daylight Saving—

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Dec. 29 1231

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tures—

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Pyrometers and Pyrometry—

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Pyrometers and Pyrometry (Con-
tinued)—

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Scientific Research in South Africa—

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Nov. 30 321

Electric Lighting in China—

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Gas AgeLighting of the Grand Rapids Gas
Office—

News Item

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General Electric ReviewThe Status of Illuminating Engineer-
ing—

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Street Lighting with Modern Electric
Illuminants—S. L. E. Rose and
H. E. Butler

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ing the Intensity of Illumination from			
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Photographic Journal of America			
Artistic Lighting in Photography—	Felix Raymer	Dec.	505
Proceedings Royal Society			
The Fourth Colorless Sensation in the			
Three-sensation Spectrum Curves			
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ness—	W. de W. Abney	Dec. 1	59

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Un nouveau photometre spherique pour lampes a incandescence—	News Item	Nov. 24	807
Measures de tres faibles intensities lumineuses a l'aid des variations de courant dans les tubes a vide (Ab- stract in Documentation) (Taken from Physik. Zeit. t. XVII, p. 268, Signale dans E. T. Z., 19 April 1917 XXXVIII, p. 224)—	Elster et Geitel	Nov. 24	162
Railway Electrical Engineer			
Electric Car Lighting—	Editorial	Dec.	318
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Efficient Laboratory Lighting—	W. M. Atwood	Dec. 28	641
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Science Abstracts (Section B)			
Comparative Study of Arc Lamps and Gas-filled Tungsten Glow-lamps (Abstract from Zeits. Vereines Deutsch. Ing. 61, p. 625, July 28, 1917)—	Heyck	Oct. 31	392
Illumination Studies (Abstract from Elektrot. u. Maschinenbau, 35, p. 223, May 6, 1917)—	N. A. Halbertsma	Oct. 31	394
Scientific American			
Where do We Stand in Optics—	Letter by James P. C. Southall	Dec. 15	455
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TRANSACTIONS

OF THE

Illuminating Engineering Society

PART I -- SOCIETY AFFAIRS

VOL. XIII

MARCH 20, 1918

No. 2

COUNCIL NOTES.

ITEMS OF INTEREST FROM THE COUNCIL MEETING OF FEBRUARY 14, 1918.

Annual Convention Details.

The Committee on Time and Place for the annual convention made a tentative report at this meeting of Council. The members of this committee, on which are representatives of each Section, reached the decision that the usual annual convention, including the entertainment features and excursions, was undesirable at this time. The consensus of opinion, however, seemed to be in favor of a short technical session. These actions were arrived at through correspondence. Council approved the report and decided that a one-day technical session consisting of papers on lighting subjects pertaining to the war should be held. Details as to time and place were left in the hands of the committee which was to make further recommendations to Council as may seem advisable in the light of future conditions.

I. E. S. to Co-operate with Bureau of Standards.

Upon request of the Bureau of Stand-

ards Council authorized the Committee on Lighting Legislation to call a meeting for the purpose of considering the Bureau's request to recommend minimum values for illumination of subways, switchboard rooms, power stations and sub-stations, storage battery rooms, and other places where electrical equipment is operated. These recommendations will be considered by the Bureau of Standards for insertion in the National Electric Safety Code.

Report of General Secretary.

A report of the status of membership in numbers and activities in the various Sections was presented. The total number of Members and Associate Members divided among the various Sections are as follows:

	Members	Associate Members
Chicago	35	112
New York	140	273
New England	25	61
Philadelphia	65	239
Pittsburgh	40	65
Non-Section	39	123
Total	344	873

A committee was organized for the purpose of determining the advantages and disadvantages to be derived from

holding only a few long-session meetings per year as compared to the regular monthly meetings in each Section. This question is one raised by the war-time condition which affects the personal, military and civilian interests of the membership. The recent three-session all day meeting of the Pittsburgh Section—its first meeting of the present fiscal year—was highly successful from the standpoint of attendance and interest shown in the papers. On the other hand the monthly meetings of the Chicago, Philadelphia and New York Sections present examples of the usual business routines which seem to have been little affected by war conditions.

New Members.

Upon recommendation of the Board of Examiners the following applicants were elected to membership:

Six Associate Members.

BARRETT, J. G.

Illuminating Engineer,
Texas Power & Light Co.,
Interurban Bldg.,
Dallas, Texas.

CRAIGUE, NORMAN A.

Testing Engineer,
E. I. duPont de Nemours & Co.,
Wilmington, Del.

MUROTA, HANNOSUKE

Electrical Engineer,
Tokyo Electric Co.,
Kawasaki, Kanagawa-ken, Japan

McKAIG, W. WALLACE

Mechanical Engineer,
Cumberland, Md.

PELTON, ERNEST W.

Superintendent of Power and Construction,
The Stanley Works,
New Britain, Conn.

STROUD, FREDERICK GEORGE

Chief Electrician,
Public Works Dept.,
Parliament Bldg.,
Toronto, Ont.

SPECIAL I. E. S. MEETING.

Held in New York on February
14, 1918.

Subject: "Lighting Curtailment." See paper in full in this number of the TRANSACTIONS.

A general session of the Society was held at the Engineering Societies' Building, New York City, on February 14th. The meeting was for the purpose of considering the extent to which the lighting industry could co-operate in the conservation of fuel. A paper entitled "Lighting Curtailment" was presented by Mr. Preston S. Millar, General Manager of the Electrical Testing Laboratories, New York; and discussed by many prominent officials of lighting companies, architects, physicians, editors and representatives of manufacturing companies. Invitations were extended to representatives of the Fuel Administration to discuss the paper. Acknowledging letters from these officials were read at the meeting and expressed their regret that their emergency duties prevented attendance.

Among those who discussed the paper were Louis Bell, H. Calvert, S. E. Doane, Wm. A. Durgin, Wm. J. Hammer, Bassett Jones, John W. Lieb, M. G. Lloyd, Norman Macbeth, Preston S. Millar, Wm. LeRoy Robertson, W. H. Rolinson, Arthur J. Rowland, W. D'A. Ryan, Wm. J. Serrill, R. E. Simpson, Frank W. Smith, G. H. Stickney, and Frank Wallis.

Mr. Millar's investigations pointed out

that the total coal consumed in producing electric light was only 2 per cent. of the total consumption in the country. *Curtailment of this 2 per cent. used for lighting, as compared to the curtailment of 98 per cent. of fuel used for heating, locomotion, and other purposes, appears, therefore, to be relatively negligible.* This paper recommended a readjustment of the present lighting intensities, in general emphasizing the importance of increased intensities and proper use of light for war-time protective purposes, and recommending a conservative decrease in intensities in some special civilian lighting services. The balance of desirable readjustments, however, resulted in a net decrease of only 3 per cent.

This curtailment (3 per cent.) would result in a saving of about 340,000 tons of coal per year—a little more than five one-hundredths of 1 per cent. of the total. The disadvantages which would probably result through a radical decrease of intensity in residential and business districts, involving danger to life and property, were pointed out. Comparisons of total coal consumption, consumption for light and power, and the savings to be effected through curtailment of light and heat were shown by means of charts. The paper gave in detail the results of the author's investigations. The trend of the discussions on the paper upheld the author's contentions. Emphasis was placed on the necessity for care in the use of fuel for heating purposes.

About two hundred and fifty members and interested guests attended the meeting. The representation from the various sections of the country was a proof of the vital interest in the subject. Considering that the meeting was authorized by the Council Executive Committee on January 29th and all preparations for

the meeting were completed within two weeks, the attendance was truly gratifying. The paper was also presented by the author on February 15th before the Philadelphia Section of the Society.

The demand for reprints of this paper has been so wide that the Society has made arrangements to print the revised edition and to distribute them at cost. Orders for the paper should be sent to the Illuminating Engineering Society, 29 West 39th Street, New York, N. Y. The reprints may be obtained on an excellent grade of suede finish paper with cardboard covers or on a cheaper grade of coated stock. Orders for large quantities should reach the General Office not later than March 30, 1918. When sending in orders kindly indicate whether the discussions are to be printed with the paper.

SECTION ACTIVITIES.

SCHEDULE OF MEETINGS

(Announced to the General Office prior to publication. Subject to revision.)

NEW YORK.

March 14—"An Aspect of Light, Shade and Color in Modern Warfare," by M. Luckiesh.

PHILADELPHIA.

March 15—"The Aesthetics of Street Lighting," by M. Luckiesh.

CHICAGO.

March 21—"The Relation of the Bureau of Standards to Illuminating Engineering," by M. G. Lloyd.

April 18—"Regulation of Street Series Lamps in Practice," by F. A. Vaughn.

PITTSBURGH.

Announcement pending.

NEW ENGLAND.

Announcement pending.

NEW YORK.

Meeting of the Board of Managers,
January 31, 1918.

It was decided at this meeting that because of the general meeting of the

Society on February 14th, the regular New York Section meeting would be canceled; to set back the programs of the Papers Committee by one month.

The membership Committee reported that it had followed out its publicity scheme for the Society, and was extending invitations to a number of contractors and fixture dealers in the Newark territory to attend meetings of the Section.

A discussion was held on the advisability of a more vigorous new membership attempt. The consensus of opinion was that this was not a propitious time to start any membership drive, yet a certain amount of new membership work might be done among people to whom the Society could be made useful and who could be of use to the Society. The question of just what form the new membership activity would take was left to be discussed at the next meeting when a list of men who should join the Society would be available.

CHICAGO.

Section Meeting of February 21, 1918.

Mr. M. Luckiesh presented a paper on "The Lighting Art—Its Practice and Possibilities in Interiors" before this Section on February 21st. The paper was discussed by Messrs. J. R. Cravath and L. Robertson. Some sixty members and guests attended the meeting which was held in the Auditorium of the Western Society of Electrical Engineers, Monadnock Block.

PHILADELPHIA.

Meeting of February 15, 1918.

An informal dinner at the Engineers' Club preceded the presentation of the paper on "Lighting Curtailment" by Mr. Preston S. Millar. Approximately fifty members and guests were in attendance. A lively discussion followed the abstrac-

tion of the paper which had been given before the special meeting of the Society held in New York on the preceding evening.

Membership Activities.

A letter to superintendents and managers of department stores and commercial establishments in Philadelphia has been circulated by Mr. R. B. Duncan of the local Membership Committee. It points out that men who are responsible for lighting installations in their organizations should be in touch with recent developments in their field and should therefore be members of the Society. It further affirms that proper applications of illumination require technical knowledge and expert judgment and a contact with engineers and artisans whose daily routines contemplate these problems.

COMMITTEE ACTIVITIES.

Committee on Automobile Headlighting Specifications.

To observe the effects on vision of the headlamp from an approaching automobile and at the same time to consider the visibility of objects illuminated by his own headlamps, *and to be able to adjust the intensities of these two*, are the unique experiences of members of the Illuminating Engineering Society Committee on Automobile Headlighting Specifications and the Light Division of the Standards Committee of the Society of Automotive Engineers. An extended meeting of these committees was held in New York on March 4th and 5th. On March 4th, the plans and general procedure to be followed were outlined and the apparatus provided for the tests was set up and inspected.

A series of working tests of intensity,

visibility and distance-of-observation were run on a test road, running from Pelham Parkway through the Morris Park station of the New York, Westchester and Boston Railroads in the Borough of the Bronx, New York. A "test-car" was stationed at various distances from the observer who looked towards this car. This observer also had a "test-car" lamp equipment which served to illuminate the road from his "own" car. By means of long cables attached to both cars and a series of controlling rheostats, the observer could adjust the intensities of each lamp equipment. These first tests were run with a paraboloid reflector with plain cover glass.

An invitation to participate in this test was extended to a large number of organizations of automobilists and to state and municipal legislators, administrators and police officials for the purpose of being able to collect a body of experienced observers whose opinions would be competent and unbiased.

Among those who had accepted this invitation up to the time of going to press were the following:

- A. L. Atwood, Street Board Public Roads, Providence, R. I.
- H. W. Baker, N. Y. State Automobile Association.
- A. G. Batchelder, American Automobile Association, Riggs Bldg., Washington, D. C.
- Wm. L. Dill, Commissioner Motor Vehicles, Trenton, N. J.
- B. H. Divine, N. Y. State Motor Federation.
- Prof. F. R. Hutton, Senate Chambers, Albany, N. Y.
- F. M. Hugo, Secretary of State, Albany, N. Y.
- J. A. McDonald, Deputy Commissioner, Hartford, Conn.

J. J. McInerney, N. Y. State Motor Federation, Rochester, N. Y.
Inspector Myers, Traffic Squad, New York City.

C. M. Talbert.

Michael M. Van Buren, Street Board Public Roads, Providence, R. I.

G. R. Wellington, Chief Clerk, Automobile Dept., Providence, R. I.

The members of the S. A. E. and I. E. S. Committees and officials of the two societies were in charge of the tests. Further details and results of the tests will be announced in a future issue of the TRANSACTIONS.

Committee on Membership.

The Committee on Membership consists of a Chairman and two members, the latter being respectively the Chairman of the Committee on Individual Membership and the Committee on Sustaining Membership. This Committee of three acts in an advisory capacity dealing with the membership campaigns conducted by the Committees on Membership and Sustaining Membership. Through the efforts of this Committee the entire work of increasing membership is co-ordinated and systematized.

A meeting of the Committee on Membership was held at the General Office on Monday, February 25th, at which time the status of the membership was reviewed and definite plans made for increasing both individual and sustaining membership. The Chairman of the Committee on Individual Membership has this year expressed his desire to co-ordinate the membership activities of the local sections and to aid them in whatever local arrangements they may make.

The personnel of both committees on

membership will be found in the front of the TRANSACTIONS.

Committee on Education.

The work being undertaken by this Committee is that of outlining a course in illuminating engineering which will be suitable for a one year's course adapted to the requirements of students taking some engineering or scientific course as their major. The major for illuminating engineering has been outlined by previous members of the Society as well as a one year supplementary course, but this Committee believes that a one year's course would be useful to schools that are not giving longer courses.

Committee on Research.

This Committee reports that in spite of the activities of its members it nevertheless hopes that before the end of the current year the Committee may make some progress in heterochromatic photometry which has been under consideration for several years.

Committee on Lectures to Architectural Students.

Reports from this Committee indicate that the completion of the lectures is now under way. Previous work on these lectures has been delayed due to the activities of the members of the Committee on special war work.

Committee on Papers.

Due to the wide geographical distribution of the members the business of this Committee has been carried on through the medium of circular letters. The consensus of opinion, thus expressed through correspondence, has guided the decisions of the Committee in securing the papers for presentation

and publication. All of the Correspondence Convention papers which were issued in the last calendar year were approved by this Committee. A number of other papers presented before sections and the paper on "Lighting Curtailment" presented before the General Meeting of the Society on February 14th, have also been approved by this Committee. The Correspondence Convention papers have for the most part been published in recent issues of the TRANSACTIONS; several papers, however, are still awaiting publication. At the present time there is a proposal before the Committee that in view of the war situation a symposium be prepared on the *maintenance of lamps and glassware*, with a view to increasing efficiency of illumination.

Committee on Popular Lectures.

Work of this Committee is now well under way. It is proposed to complete at least two more popular lectures this year. One of these is on "Protective Lighting" and another on "Industrial Lighting."

Lectures previously prepared by this Committee are on the subjects of "Home Lighting" and "Store Lighting." These lectures with accompanying slides may be obtained for presentation from the General Office.

LOCAL REPRESENTATIVES.

Syracuse, N. Y.

Mr. R. A. Porter, Local Representative in this district, delivered the popular lecture on "Home Lighting" at the Technology Club of Syracuse, on February 13th. Those who attended showed great interest in the text of the lecture and in the slides. The audience expressed to the Society and to Mr. Porter

a vote of thanks for the privilege of hearing the lecture.

Cleveland, Ohio.

Mr. Ward Harrison, Local Representative in this district, was in charge of the local arrangements for the Pittsburgh Section meeting which was held in Cleveland in December. The evening program was presented jointly before the Pittsburgh Section of the I. E. S. and the Cleveland Section of the A. I. E. E. Mr. R. B. Chillas delivered a paper on searchlamps, dealing particularly with the new *flame* type. Mr. M. Luckiesh lectured on the wartime applications of the fundamental principles of light, shade and color; dealing in some detail with the art of camouflage.

Mention of this session of the meeting was omitted from the preceding number of the TRANSACTIONS because of lack of definite information.

Springfield, Mass.

Mr. W. E. Hodge, Local Representative of the Society, presented the popular lecture on "Home Lighting" before the Employees' Association of the United Electric Light Co. of Springfield early in February. The presentation was greatly appreciated by all those present who requested Mr. Hodge to express to the Society their thanks for the loan of the lecture.

Toronto, Canada.

An item of interest has come from Mr. H. D. Burnett, Local Representative at Toronto, Canada, regarding the popular lectures, which he had anticipated giving. Under the present conditions, Toronto has been obliged to curtail lighting everywhere, cutting off all window (store) lighting during both day and night, and one-half or more of

all lights wherever possible. Therefore Mr. Burnett feels that this is an inopportune time to agitate better lighting, but hopes that at some future time, assisted by favorable conditions, some progress could be made. Mr. Burnett adds that he will be glad to consider any suggestions that members of the Society may have to make.

(A careful review of the paper and discussions on "Lighting Curtailment," in this issue, will no doubt be helpful to many users of light in Toronto.—ED.)

I. E. S. WAR NOTES.

Honor Roll.

The following additional members of the Society have become affiliated with the active military or naval service of the United States. The names of other members who have previously enlisted have appeared in the TRANSACTIONS, Vol. XII (Nos. 6, 7, and 8).

E. A. Anderson
E. E. Ashley
T. T. Barnett
N. M. Black
F. W. Chapman
Darwin Curtis
H. W. Edmund
C. E. Egeler
A. A. Folz
F. H. Gilpin
K. R. Hare
H. E. Ives
E. F. Kingsbury
M. N. Liebmann
R. C. Macdonald
S. L. Marlow
C. O. Martin
F. L. Mason
C. T. Melvin
F. J. Miller
T. E. Moon
A. B. Oday

G. S. Parker
 C. W. Pike
 E. H. Robnett
 J. J. Spillan
 A. S. Turner
 F. S. Wilson
 M. G. Woolfson

Emphasizing the Need for Plant Protection by Guards and Lighting.

On January 26th a fire occurred at Port Newark Terminal, New Jersey, causing damage estimated at about \$400,000. In the United States Official Bulletin of February 19th appears a statement, authorized by the Department of Justice regarding the cause of the fire. The following is excerpted, the italics being our own:

The result of this investigation calls attention again to the impossibility of safe-guarding water-front facilities by means of military guards, unless the owners co-operate by taking all proper precautions. Here, as in most other cases, damage came from internal causes. In this particular case, the contractors, simply because a military guard was furnished for the outside of the premises, appear to have cast aside all sense of responsibility for the internal supervision of the premises. The disaster emphasizes the duty of private owners to provide proper protection in the way of expert watchmen, *proper lighting facilities*, etc., on the premises themselves. It demonstrates anew the *folly of manufacturers demanding military guards and at the same time failing to meet the duty laid on them of taking extraordinary precautions* within the plants to protect against damage. The investigation shows a gross neglect of even the most ordinary precaution and watchfulness.

Members of this Society are of course aware of the importance of protective lighting. It is evident, however, that all those responsible for guarding property essential to the prosecution of the war and the welfare of the public do not recognize this need.

A letter of recent date of Mr. Augus-

tus D. Curtis advises us that the National X-Ray Reflector Company has twenty-eight members who have joined the Colors. Two sons of Mr. Curtis are also in the service.

Military Service in Ordnance Department.

The Ordnance Department of the Army is conducting a campaign to obtain recruits for that department for service in the United States. Positions are open for employment in the following occupations:

Testing: Engineers of tests of ordnance materials.

Mechanical Trades: Machinists, drop forgers, tool-makers.

Drafting: Mechanical and gauge designers.

Inspection: Inspectors of artillery ammunition, small arms, cannon forgings, gunfire control instruments, and explosives.

Clerical: Stenographers, typists, catalogue clerks, accountants and statisticians.

Applications and inquiries should be addressed to John A. McIlhenny, President, U. S. Civil Service Commission, Washington, D. C.

Illuminating Engineers Wanted.

A number of high class engineers proficient in the principles and practice of illuminating and electrical engineering are wanted for enlistment in the Fifty-sixth U. S. Engineers (Searchlamp Regiment). This regiment is being organized for special service abroad. Those whose training and inclination to help the country through immediate application of their engineering experience should apply to Alexander Macomber, Captain, Engineers Reserve Corps, Washington Barracks, D. C.

NEWS ITEMS.

Code of Lighting School Buildings.

The Code of Lighting School Buildings which was circulated for the purpose of receiving criticisms and suggestions has now been revised by the Committee on Lighting Legislation and approved for publication by the Committee on Papers.

There are 20,000,000 school children in the United States who are devoting several hours each day to study or to the performance of other work equally trying to the eyes. According to the available statistics nearly 10 per cent. of the number of school children examined are found to have defective vision.

The severe requirements imposed upon children's eyes by modern educational methods create need for the best of working conditions. Among these conditions lighting is of first importance. Improper lighting causes eye-strain, resulting in functional disorders, near-sightedness and other defects of the eyes.

The Code of Lighting School Buildings has been prepared by committees of the Illuminating Engineering Society in order to make available authoritative information for legislative bodies, school boards and others who are interested in enactments, rules and regulations for better lighting.

While the Code is intended primarily as an aid in formulating legislation relating to the lighting of school buildings, it is also intended for school authorities as a guide in individual efforts to improve lighting conditions.

The criticisms and suggestions for improving the Code have come from prominent architects, engineers, lighting experts and educators throughout the country. Their contributions have been

of material aid to the Committee in the work of revision.

Engineering Council.

The General Office is in receipt of the first statement of the purpose and field of the organization of technical societies known as the Engineering Council. The definition of Engineering Council adopted February 21st by the Executive Committee is as follows:

"Engineering Council is an organization of national technical societies of America created to provide for consideration of matters of common concern to engineers as well as those of public welfare in which the profession is interested in order that united action may be made possible. Engineering Council is now composed of the American Society of Civil Engineers, American Institute of Mining Engineers, American Society of Mechanical Engineers and American Institute of Electrical Engineers, having a membership of 33,000 and known as the Founder Societies."

On February 21st, the first annual meeting of Council was held at which time Mr. J. Park Channing was elected Chairman; Mr. Harold W. Buck, First Vice-Chairman; Mr. George F. Swain, Second Vice-Chairman; Mr. Alfred D. Flinn, Secretary. The following committees were appointed: *Executive, Finance, Rules, Patents, Public Affairs, War Committee of Technical Societies, and American Engineering Service.* The last Committee was organized for the purpose of obtaining professional classifications of engineers throughout the country and for indexing this information to make it available for reference to authorities of the Government in securing men proficient in all branches of engineering, and also for the purpose of supplying this data to employers seeking engineering service in civilian pursuits.

It is not the intention of Engineering Council to restrict its membership to the four Founder Societies. The fol-

lowing is a quotation from the official statement of the Executive Committee:

"It is planned and earnestly desired that other national engineering and national technical societies shall become affiliated, thus making Engineering Council truly representative of the hundred thousand engineers in all branches of the profession throughout the United States. Conditions and methods for the admission of additional societies have been developed. Henceforth, a chief aim of Engineering Council will be to increase the number of member societies and thus gain not only an enlargement of its capacity for usefulness along its chosen lines, but also greater technical and financial support."

"Unselfish service and mutual helpfulness must be the test requirements for all the undertakings of Engineering Council. Offensive political or business activities must be avoided and the selfish aims of groups or individuals must not be fostered. If the work roughly outlined be carried forward in this spirit, no fears need be entertained for the profession's ethics, its honor, or the standing of the engineer in the community."

Mr. M. Luckiesh of the Nela Research Laboratories of the National Lamp Works, Cleveland, Ohio, presented a lecture before the Engineers at Camp Sherman on February 18th. The subject of the lecture was "Electric Lighting."

Mr. William C. Bruce, Editor of the *American School Board Journal*, has secured photographs and drawings of the Code of Lighting School Buildings from the General Office and will reproduce the Code in the April issue of that journal.

Mr. J. L. Stair, Chief Engineer of the National X-Ray Reflector Company, Chicago, Ill., spoke on "Some Principles of Illumination and Their Application" before the Urbana Section of the A. I. E. E. in joint meeting with the Electrical Engineering Society, University of Illinois, on January 18th.

The paper on "Lighting Curtailment," herein, presents statistics showing that light costs the nation less than liquor. The following quotation appeared in the New York *Evening Sun* the day following the presentation of this paper:

"Maybe if it (light) cost more some people would value it more and turn from champagne to drink in the intoxicating rapture of an Edison cocktail, singing with Ben Jonson 'Drink to me only with thine eyes.'"

GENERAL OFFICE.

Sell Your Transactions.

Members can aid the Society by sending in extra copies of back numbers of the TRANSACTIONS as listed below. For each of these copies received at the General Office in good condition, the Society will remit fifty cents (50¢).

Vol. I—Nos. 1, 2, 3, 4, 5, 6, 7.

Vol. II—Nos. 1, 2, 3, 4.

Vol. III—Nos. 1, 4, 5.

Vol. VIII—Nos. 1, 2, 3, 4.

Such copies as may be received in this way will be placed for permanent reference on the shelves of libraries throughout the country. If the library in your neighborhood does not have the TRANSACTIONS please advise the General Office.

Annual Election.

The Constitution provides that the details of election of council and section officers for the next fiscal year shall commence on March 1st. A general Nominating Committee including former and present council members representing each section of the Society prepares the ticket. Each section is further represented by a local Nominating Committee appointed by the local Board of Managers. The duty of this Committee is to recommend nominees for positions on the Board of Managers for the ensuing year. Ballots indicating

the nominees for council and section officers are issued to the membership not later than May 5th, and the returns are counted by a Committee of Tellers which meets between May 26th and May 30th.

OBITUARY.

Dr. Arthur H. Elliott, a former associate member of the Society, and an expert on gases and for a number of years instructor in chemistry in Columbia University, died on Thursday at the Peekskill Hospital, Peekskill, N. Y. Dr. Elliott was born in London, England, and the same year he was graduated from the British School of Mines he started a tour of the world. Arriving in New York, Professor Chandler of Columbia, to whom he carried a letter of introduction, induced him to remain. He studied chemistry at Columbia and was graduated in sciences in 1881, after which he became an instructor in the university.

Dr. Elliott held the following posi-

tions during his affiliation with the Society: General Secretary, 1906; Treasurer, 1907, 1908, 1909; and was a member of the following committees: Committee on Editing and Publication, Board of Examiners.

Word has been received at the General Office that Mr. Charles Oliver Smith who was an associate member of the Society was accidentally killed on November 21st, at the power plant of the Lewis County Light & Telephone Company which he owned at Morton, Wash. He was caught in a small belt and taken around the line shaft.

Word has been received from the Philadelphia Section that Mr. J. W. Stirzel, a member of the Society, died in this past month. Mr. Stirzel was connected with the United Gas Improvement Co., Philadelphia Gas Works, Philadelphia, Pa.

Mr. Thomas W. Byrne, a member of the New England Section, died on December 14, 1917.

ILLUMINATION INDEX.

Prepared by the Committee on Progress.

An index of references to books, papers, editorials, news and abstracts on illuminating engineering and allied subjects. This index is arranged alphabetically according to the names of the reference publications. The references are then given in order of the date of publication. Important references not appearing herein should be called to the attention of the Illuminating Engineering Society, 29 W. 39th St., New York, N. Y.

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Ideals and Near-Ideals in Lighting Units—	H. S. Brown	1918 Jan.	88
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TRANSACTIONS

OF THE

Illuminating Engineering Society

PART I -- SOCIETY AFFAIRS

VOL. XIII

APRIL 30, 1918

No. 3

COUNCIL NOTES.

ITEMS OF INTEREST FROM THE COUNCIL MEETING OF MARCH 14, 1918,

Membership.

The war, up to this time, seems to have had very little effect on the number of membership applications being presented to various engineering societies. The I. E. S. Committee on Individual Membership is gradually increasing the monthly balance of applications. The Philadelphia Section Representative of this Committee, Mr. R. B. Duncan, reports some thirty-five applications received during February and March. Mr. H. F. Wallace, representing the Committee in the New England Section, has recently obtained material from the General Office for a drive in the vicinity of Boston. The local representatives have turned in applications. A recent letter from Mr. Wm. J. Serrill, Chairman of the Committee on Membership, points out to all members the importance of introducing the work of the Society to non-members. Returns are beginning to come to the General Office as a result of this letter. Altogether the status of individual membership

gives indications of increasing considerably during the next few months.

Code of Lighting School Buildings.

All orders for quantity lots of the Code should be received at the General Office not later than May 15th. Great interest in the Code is being shown by architects, school authorities, physicians, eye specialists and others interested in the conservation of vision and proper illumination of public buildings. A number of prominent educational and civic journals have made comment on the Code in recent issues. The revised Code was presented to the Council by the Committee on Lighting Legislation on March 14th. It is printed in full in this issue.

Committee on Automobile Headlighting Specifications.

The interim report of the tests made on a piece of road between Pelham Parkway and Morris Park Station, New York (see Vol. XIII, No. 2, TRANSACTIONS), was presented to Council and referred to the Committee on Papers for publication. This report will appear in an early issue of the TRANSACTIONS.

War Committee of Technical Societies.

The I. E. S. representatives on this Committee, Messrs. L. B. Marks and

Preston S. Millar, presented a report to Council covering the functions of the Committee. The Society has received an invitation from Engineering Council to contribute an amount equal to 15 cents per member per year to conduct the work of the Committee. This is the rate now assessed to the founder Societies of Engineering Council.

Committee on War Service.

This Committee presented to Council a progress report detailing the latest services rendered to various departments of the Government. Comment on the actual work of the Committee is not permitted.

New Members.

Upon recommendation of the Board of Examiners the following applicants were elected to membership:

One Transfer to Member.

AUGUST H. MEYER

General Manager,
Bryan-Marsh Division,
431 S. Dearborn St.,
Chicago, Ill.

Seven Associate Members.

WILLIAM T. BOEHNER

Master Mechanic,
J. B. Stetson Co.,
5th St. and Montgomery Ave.,
Philadelphia, Pa.

HERBERT BROMUND

Fixture Dealer,
2337 Germantown Ave.,
Philadelphia, Pa.

FRANK WILLIAM HART

Officer, Columbia University Staff,
Teachers College,
Columbia University, N. Y.

MORRIS SKLAR

Head of Lighting Fixture Dept.,
Joseph E. Frechie & Co.,
634 Arch St.,
Philadelphia, Pa.

WILLIAM H. SMITH

Chief Engineer,
T. Eaton Co.,
190 Yonge St.,
Toronto, Canada.

H. W. TURNER

Designer,
Frank H. Stewart Electrical Co.,
37-39 N. 7th St.,
Philadelphia, Pa.

DILLWYN J. WATTIS

Chief Engineer,
J. B. Stetson Co.,
5th St. and Montgomery Ave.,
Philadelphia, Pa.

SECTION ACTIVITIES.

SCHEDULE OF MEETINGS

(Announced to the General Office prior to publication. Subject to revision.)

NEW YORK.

March 14—"An Aspect of Light, Shade and Color in Modern Warfare," by M. Luckiesh.

PHILADELPHIA.

March 15—"The Aesthetics of Street Lighting," by M. Luckiesh.

CHICAGO.

March 21—"The Relation of the Bureau of Standards to Illuminating Engineering," by M. G. Lloyd.

April 18—"Regulation of Street Series Lamps in Practice," by F. A. Vaughn.

PITTSBURGH.

Announcement pending.

NEW ENGLAND.

Announcement pending.

NEW YORK.**Section Meeting of March 14, 1918.**

Chairman A. S. McAllister aptly camouflaged the talk on that subject by referring to the title of Mr. Luckiesh's paper as "An Aspect of Light, Shadow and Color in Modern Warfare." Some eighty members and twenty guests enjoyed the presentation which was illustrated with many slides showing the various illusions that might be produced through adjustments of intensity, color and direction of illumination.

Mr. Luckiesh brought out the many ways in which nature provides for the protection of birds, beasts and reptiles inhabiting their natural haunts—and emphasized their high visibility when they are found in unusual surroundings or in unnatural positions. Extending these conceptions to the art of camouflage in modern warfare, it was shown that great variety of color and intensity of high lights and shadows were effective in rendering less visible the outlines and locations of military and marine equipments. On the other hand, the scientific applications of colored screens over the lenses of binoculars and cameras enabled the observers to overcome some of the illusions.

A number of representatives of military organizations interested in camouflage were in attendance. An informal dinner preceded the meeting.

PHILADELPHIA.**Section Meeting of March 15, 1918.**

The meeting was preceded by the usual dinner at which twenty-six members and guests were in attendance. On opening the meeting the Chairman of the Membership Committee announced that thirty new members had been obtained for the Section with favorable prospects of obtaining at least ten more.

Mr. Lyon then gave a talk on "The Nomenclature of Illuminating Engineering" with special reference to intensities distributed over the surface of a sphere, using as his model a wooden ball cut into zones to illustrate this distribution.

Mr. S. E. Doane who had expected to deliver a paper on "The Esthetics of Street Lighting" was prevented from attending the meeting and sent as his representative Mr. M. Luckiesh, physicist of the Nela Research Laboratories at Cleveland, who spoke on the same subject. His talk was profusely illustrated by means of lantern slides showing undesirable forms of street lighting, means of supporting trolley wires, etc. He showed street scenes in some cities where the combination of poles and wires was a disgrace and marred what otherwise would be attractive streets. His talk was a plea for the improvement of civic conditions which could be partially accomplished by removing undesirable bill-boards and unnecessary trolley, electric light and telephone poles.

The meeting was attended by one hundred persons. The discussion which followed the presentation of the paper was not confined strictly to street lighting, but extended to methods of distributing overhead wires.

CHICAGO.**Section Meeting of March 21, 1918.**

Dr. M. G. Lloyd, electrical engineer of the Bureau of Standards, presented a paper on "The Relation of the Bureau of Standards to Illuminating Engineering" which was discussed by Messrs. F. H. Bernhard, J. J. Ryan, J. C. Hall, E. H. Freeman, E. M. Tomkins, and James R. Cravath. About thirty members and guests attended the meeting. The paper was illustrated with lantern slides.

During the discussion Dr. Lloyd brought out the fact that the Bureau of Standards had commenced to prepare specifications for street lighting. The work is being done in conjunction with committees of utility and engineering associations. After collecting statistics and making a study of methods already in use, it is the intention to draw up model forms of contract embodying the best information available. A comprehensive publication dealing fully with the entire subject will eventually be issued.

Among the illustrations were typical distribution curves for automobile headlights, many types of which have been investigated at the Bureau. One matter discussed was the specifications under which this year's supply of incandescent lamps to the Government will be furnished.

LOCAL REPRESENTATIVES.

Newark, N. J.

Colonel Lewis T. Bryant, Commissioner of Labor of the State of New Jersey, issued an invitation to manufacturers, architects and contractors in the Essex district to attend a meeting held under the auspices of the State Department of Labor, the Manufacturers Branch of the Newark Chamber of Commerce and the Illuminating Engineering Society at the Council Chamber, City Hall, Newark, N. J., on April 14th. Mr. J. N. Adam, local representative in Newark, co-operated with Colonel Bryant in conducting this meeting.

It was brought out that the function of the State in enforcing its lighting code was similar to that of enforcing its

health regulations inasmuch as it should only go that far as demanded by the welfare of its workers. In this respect the New Jersey Code was declared to prescribe intensities and conditions very much below what the interests of the manufacturer himself would dictate. Emergency lighting systems independent of the regular installation was urged upon manufacturers for the complete protection of their workers.

The following members of the Society were among those who took part in the discussions: George H. Stickney, President; Louis B. Marks, Chairman of the Committee on Lighting Legislation; Roland H. Leveridge, Chief of the Bureau of Electrical Equipment of the State Labor Department; R. ff. Pierce, of the Welsbach Co.; A. L. Powell, Edison Lamp Works. William B. Gwinnell, Chairman of the Manufacturers' Section of the Board of Trade of Newark, presided as Chairman of the meeting.

Mr. J. N. Adam informs the Society that it is his intention to co-operate with Colonel Bryant in conducting similar meetings in other sections of the State of New Jersey.

Milwaukee, Wis.

Mr. F. A. Vaughn, local representative, reports that the I. E. S. lectures on Home Lighting, Store Lighting, and the Code of Lighting School Buildings were presented before the electrical exhibition of the Milwaukee School of Engineering during April. The lantern slides for the Code of Lighting Factories, Mills and Other Work Places were presented at the electrical exhibition by Mr. J. A. Hoeveler, illuminating engineer for the Wisconsin Industrial Commission.

Providence, R. I.

The Power Section of the Providence Engineering Society held a meeting on Wednesday, April 10th, at which one of the principal papers dealt with "Mill Lighting." The speaker of the evening was Mr. F. W. Bliss. Mr. F. A. Gallagher, Jr., local representative of the Society in Providence, presented an extensive and interesting discussion of this subject placing particular emphasis upon the fundamentals of good lighting. Mr. Gallagher reports that he hopes to make a prominent issue of the problem of industrial lighting before the full meeting of the combined Society Sections in Providence in the near future.

I. E. S. WAR NOTES.

War Service.

A folder summarizing the activities of the Society in the prosecution of the war has recently been issued by the I. E. S. Committee on Membership. The text of this folder, printed below, war has recently been issued by the I. E. S. Committee on Membership. is worthy of careful thought and should be an inspiration to every member of the Society who in his daily routines adds to the science and disseminates knowledge on the use and misuse of light and thereby helps to *win the war*.

"Light properly controlled is a very important instrument for winning the war.

"AT THE FRONT OR ON THE SEA it reveals and locates the enemy, his works, operations, submarines. It also conceals our own operations by camouflage or glare. It conveys intelligence by signals, even in the daytime.

"AT HOME it protects buildings, piers, bridges and other works; it speeds production and prevents waste. It prevents accidents which jeopardize life and material.

"It conserves eyesight; gives cheer and comfort to workers.

"As soon as war was declared, the Society offered its services to the Government. Since then it has lost no opportunity to be of service. Its Committee on War Service, acting upon requests received directly or through the National Committee on Gas and Electric Service, has designed lighting installations for various departments of the Government. The Committee has also prepared a Treatise on Protective Lighting at the request of Government officials.

"Members nominated by the Society constituting the Divisional Committee on Lighting under the Committee on Labor, of the Council of National Defense, have prepared a Treatise on Industrial Lighting for application wherever work is done under contract with the Government. Lighting experts for each State in the Union have been selected to co-operate.

"The National Research Council has availed itself of the services of the Society's experts in prosecuting its researches on problems of lighting and vision.

"The Society's membership has been classified so that the Government may have ready access to lighting specialists.

"Dues have been remitted to members who have entered military service.

"These activities are making large demands on the Society's resources; more members are needed if its service to the Government is not to be impeded."

Win-the-War Spirit in Business Letters.

The Department of Commerce under date of March 28, 1918, issued a bulletin under the above caption strongly urging that all business letters not only in this country but also those which reach foreign countries carry with them a spirit portraying confidence in allied victory. Following is a quotation from this bulletin:

"Let the American business man make known to the whole world that he is for this war and that he is going to see it through, regardless of inconvenience, loss of trade, loss of money, or anything else. Every manufac-

turer ought to be fearless in expressing his sentiments, even though he may be writing to a concern whose sympathies he may suspect are not wholly with us. Don't give a foreign concern the idea that you are apologizing for your Government's restrictions or that you are chafing under them. Spread the impression, the absolutely correct impression, that over here we are backing this war unqualifiedly."

Emergency Fleet News.

The *Emergency Fleet News* published March 18, 1918, contains the following article for lighting shipyards:

FENCING AND LIGHTING OF SHIP-YARDS ORDERED.

An order sent to the district officers and supervisors by the vice-president and general manager, March 4th, directs that proper provision be made for fencing and lighting of plants building ships for the Emergency Fleet Corporation.

War Convention in Cleveland.

A War Convention of those interested in the machinery and supply trade in Cleveland will be held in that city during the week of May 13th. The keynote of the convention will be to co-ordinate the production of "More ships, more shells." No doubt the welfare of the workers and the increased production due to proper illumination will be mentioned during this convention.

NEWS ITEMS.

Eye Hazards in Industrial Occupations.

The National Committee for the Prevention of Blindness has recently issued a pamphlet under the above caption, prepared by Gordon L. Berry, field secretary of the Committee. This contains

much valuable material, and like other literature of this important Committee, does not fail to include illumination as an important factor in industrial activity. That part of the pamphlet devoted to the subject of lighting includes discussion upon the following points:

Importance of good lighting to industrial success.

Importance of good lighting to accident prevention.

Day lighting.

Glare and shadows.

Office lighting.

Lighting equipment.

Local *versus* general illumination.

References are made to the Illuminating Engineering Society's publications as follows:

Light, Its Use and Misuse.

Code of Lighting Factories, Mills and Other Work Places.

Code of Lighting School Buildings.

In connection with intensities of illumination for office lighting the following information is supplied:

Office Lighting.—In large installations of importance, expert advice should be obtained if best illumination results are to be had. Often useful assistance can be obtained from local lighting companies. For general guidance, however, it may be stated that illumination of the order of 4 foot-candles (lumens per square foot) on the working plane is regarded as reasonably satisfactory for the generality of offices. Under various conditions illumination of this value may be obtained with energy expenditure of the order indicated in the following table:

WATTS PER SQUARE FOOT TO YIELD FOUR FOOT-CANDLES (LUMENS PER SQUARE FOOT).*

Finish		Tungsten filament lamps					
		Direct lighting system		Semi-indirect lighting system		Indirect lighting system	
Ceiling	Walls	Vacuum	Gas filled	Vacuum	Gas filled	Vacuum	Gas filled
White	Light	0.67	0.55	0.89	0.74	1.15	0.95
Cream or ivory	Medium	0.73	0.60	1.0	0.83	1.33	1.11
Light buff		0.8	0.67	1.14	0.95	2.0	1.67

* The data regarding electrical illumination were compiled by the Electrical Testing Laboratories, New York, at the request of the Committee.

CUBIC FEET OF GAS PER SQUARE FOOT TO YIELD FOUR FOOT-CANDLES (LUMENS PER SQUARE FOOT).**

Finish		Gas mantle lamps (inverted)		
		Direct lighting system	Semi-indirect lighting system	Indirect lighting system
Ceiling	Walls	Cluster units	Cluster units	Cluster units
White	Light	0.030	0.042	0.084
Cream or ivory	Medium	0.036	0.050	0.100
Light or buff	Dark	0.042	0.058	0.146

** The data regarding gas illumination contributed by the Consolidated Gas Company, New York.

That is to say, depending upon the reflecting qualities of the interior finish of the office and upon the character of the lighting equipment, as well as upon the type of lamps used, one may obtain illumination of 4 foot-candles on the working plane with expenditures of energy ranging from a minimum of 0.55 to 2.0 watts per square foot for electric lighting, and a minimum of 0.030 to 0.146 cu. ft. of gas per square foot for gas lighting. Illumination of higher intensity may be obtained under like conditions with proportionately greater expenditures of energy.

In the *Official Bulletin* for March 14, 1918, there is given a list of commissions and committees which have been appointed by the British Reconstruction Ministry to deal with questions which will arise at the close of the war. There are fifteen groups with a total of eighty-

seven committees. In the scientific and industrial research group there are twenty-one committees, one of which is as follows:

Joint Standing Committee on Illuminating Engineering—To survey the field for research on illumination and illuminating engineering, and to advise as to the direction in which research can be undertaken with advantage.

The United States Public Health Service has just issued a pamphlet "Miscellaneous Publication No. 17" entitled "Prevention of Disease and Care of the Sick." This very properly includes a brief discussion of lighting. In spite of technical misapprehensions regarding the physical aspects of lighting which are not surprising when exhibited by medical authorities, this publication should assist in drawing the attention

of the public to the importance of good lighting as a factor in the prevention of disease and care of the sick.

Mr. Francis A. Vaughn, senior member of the firm Vaughn & Meyer, consulting engineers, Milwaukee, has been engaged by the School of Engineering of Milwaukee as business manager. Mr. Vaughn and Mr. Chas. L. Pillsbury, consulting engineer of Minneapolis, are in charge of an electrical exhibition to be held under the auspices of the School of Engineering in Milwaukee from March 27th to 30th inclusive. All of the lantern slides for the various popular lectures of the Society have been forwarded to Mr. Vaughn for his use at that exhibition.

GENERAL OFFICE.

Sell Your Transactions.

Members can aid the Society by sending in extra copies of back numbers of the TRANSACTIONS as listed below. For each of these copies received at the General Office in good condition, the Society will remit fifty cents (50¢).

Vol. I—Nos. 1, 2, 3, 4, 5, 6, 7.

Vol. II—Nos. 1, 2, 3, 4.

Vol. III—Nos. 1, 4, 5.

Vol. VIII—Nos. 1, 2, 3, 4.

Such copies as may be received in this way will be placed for permanent reference on the shelves of libraries throughout the country. If the library in your neighborhood does not have the TRANSACTIONS please advise the General Office.

Mr. M. Luckiesh presented a lecture on "The Fundamentals of Camouflage" before the 308th Engineers' Regiment at Camp Sherman on April 1, 1918.

A recent number of *Farm and Fireside* prints an article indicating that the writer has confirmed the fact that hens which are housed under electric light produce eggs more abundantly. He states that for each 400 sq. ft. of floor area there should be provided about 60 candlepower. The cost of lighting a house to accommodate 500 hens by electric light runs from \$3 to \$4 a month. The author cautions that there is danger in overdoing the light and recommends that the hens should not be kept active over a total of fourteen hours during the day under both natural and artificial light conditions.

ILLUMINATION INDEX.

Prepared by the Committee on Progress.

An index of references to books, papers, editorials, news and abstracts on illuminating engineering and allied subjects. This index is arranged alphabetically according to the names of the reference publications. The references are then given in order of the date of publication. Important references not appearing herein should be called to the attention of the Illuminating Engineering Society, 29 W. 39th St., New York, N. Y.

		DATE	PAGE
American Gas Engineering Journal		1918	
Gas vs. Electric Lighting in Regard to the Solution of Wartime Problems—	R. ff. Pierce	Feb. 9	134
Entire Factory Equipped with Gas Lights—	S. E. Wardell	Feb. 16	145
American Journal of Psychology			
On "Retiring" and "Advancing" Colors—	M. Luckiesh	Apr.	182
British Journal of Psychology			
The Theory of Binocular Color Mixture, II—	S. Dawson	1917 Dec.	1
Central Station		1918	
Mazda Lamp Development to Date—	H. W. Mateer	Feb.	182
The Latest Information on Incandescent Lamps—	H. W. Mateer	Mar.	213
Electrician			
Mr. A. P. Trotter's Presidential Address to the Illuminating Engineering Society—		1917 Dec. 28	502
The Varied Applications of Light—	Editorial	Dec. 28	497
Ten Years of Illuminating Engineering: Its Lessons and Future Prospects—	News Item	1918 Jan. 25	609
A New Globe Photometer for Incandescent Lamps—	R. Von Voss	Feb. 1	630
Methods of Camouflage—	News Item	Feb. 1	627
The Present and Future Electric Street Lighting in Islington—	H. T. Harrison	Feb. 15	690
Electrical Record			
Application of Electricity in the Growing of Corn and Sugar Beets—	News Item	Mar.	37

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Electrical Review (London)		1918	
Illuminating Engineering—	S. O. Cook	Jan. 25	81
Industrial Research—	G. B. Barham	Jan. 25	93
Corrections for the Pentane Lamp—	News Item	Feb. 1	116
A Light Detector for the Blind—	News Item	Feb. 22	184
Electrical Review (U. S.)			
"Daylight Saving" Plan for Entire Year Receiving More Favor—	News Item	Feb. 9	236
Daylight Saving—	Editorial	Mar. 23	516
Performance of Metallic Filament Lamps on Alternating Current Circuits (Bull. Eng. Experiment Station, Penna. State College)—			
Electrical Times			
Tungsten Lamp Filaments—	News Item	Jan. 17	52
Electricity in Agriculture—	News Item	Jan. 31	76
Electrical World			
Testing Arc Lights Under Pressure (Abstract)—	W. Matthiesen	Feb. 2	262
White Way Lighting Begun in New Orleans—	News Item	Feb. 9	297
Electric Lamps in Non-Gaseous Mines (Abstract)—	G. H. Deike	Feb. 9	314
The Curtailment of Lighting—	Editorial	Feb. 23	393
Much Discussion on the Curtailment of Lighting—	News Item	Feb. 23	426
Broader Aspects of Research Work—	Editorial	Mar. 2	445
Initial Current Obtained in Incandes- cent Lamps—	C. J. Berry	Mar. 2	459
Quartz Mercury-Vapor Lamp for Ultra-Violet Light—	News Item	Mar. 2	491
Features of Chicago's New Parkway Lighting System—	News Item	Mar. 9	516
New Research Laboratory is Organ- ized in Japan—	News Item	Mar. 16	576
Changing Aspects of Factory Lighting Legislation—	C. E. Clewell	Mar. 23	607
Standardizing Factory Lighting—	Editorial	Mar. 23	603
Gas Industry			
War and Gas—	Theo. H. Piser	Mar.	95
Gas Journal			
Street Lamp Conversion—	News Item	Feb. 19	340
Extended "Summer Time"—		Feb. 26	388

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Gas Record		1918	
Massachusetts Reduces Standard—	News Item	Jan. 23	49
The War and Gas Lighting—	Theo. H. Piser	Feb. 27	124
Do You Believe in Gas Light?—	Chas. A. Luther	Mar. 13	145
General Electric Review			
An Improved System for Lighting Interurban Trolley Cars—	W. J. Walker	Feb.	124
Effect of Artificial Light on the Growth and Ripening of Plants—	J. L. R. Hayden and C. P. Steinmetz	Mar.	232
Illuminating Engineer (London)			
The Combination of Neon and Mer- cury Tubes for Lighting (Note)—		1917 Oct.	267
Lighting in London and the Prov- inces—	News Item	Nov.	296
Ten Years of Illuminating Engineer- ing: Its Lessons and Future Pros- pects—	L. Gaster	1918 Jan.	6
Industrial Management			
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Journal of Institute of Electrical Engineering			
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A New Neutral Tint and a Variable Tint Screen (Note)—	E. Karrer	Feb.	279
On the Luminescence of Radioactive Materials (Note)—	E. Karrer and D. H. Kabakjian	Feb.	279
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Tinting Strength of Pigments—	T. R. Briggs	Mar.	217

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National Electrical Contractor			
Direct Lighting from Open Reflector Units—	H. W. Brown	Feb.	97
National Electric Light Association Bulletin			
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Patents and Scientific Research—	News Item	Feb. 21	484
Philanthropical Magazine			
A Criticism of Wien's Distribution Law—	F. E. Wood	Feb.	190
Physics Review			
The Brightness Sensibility of the Retina—	Julian Blanchard	Feb.	81
Note on a Comparison of High-Temperature Scales—	E. P. Hyde and W. E. Forsythe	Feb.	139
Proceedings American Institute of Electrical Engineering			
A Thermoelectric Standard Cell—	C. A. Hoxie (Sec. II)	Feb.	57
Revue Generale de L'Electricite			
La Transformation des cristaux de tungstène en filaments pur les lampes à incandescence—	News Item	1917 Dec. 22	973
Lampe à arc à deux paires de charbons pour réseaux à courants polyphases de basse fréquence—	Andre Blondel	Dec. 22	975
La fabrication des lampes à incandescence au Japan (Abstract, Documentation)—		1918 Feb. 2	35
Railway Electrical Engineering			
New Night Lighting for Pullman Sleepers—	News Item	Feb.	47
Science			
The British Committee for Scientific and Industrial Research—	News Item	Mar. 15	262
The Nomenclature of Thermometric Scales—	Dr. C. F. Marvin	Mar. 15	267

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The Flickering of Metal Filament Lamps (Abstract from Elekt. Zeits. 38, p. 453, Sept. 13, 20, 27, 1917)—	K. Simons	1918 Jan. 31	52

Scientific American

Projecting Larger Pictures with the Standard Motion-Picture Film—	News Item	Jan. 26	85
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A New Cycle in Motion-Picture Projection—	News Item	Mar. 23	259
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The Relation of the State University to Research Work in War Times—	Dr. R. W. Thatcher	Feb.	124
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Transactions Illuminating Engineering Society

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Part II—Color from the Physical Point of View—	H. C. Richards	Feb. 11	7
Part III—Color in Illumination—	Beatrice Irwin	Feb. 11	14
Part IV—The Psychology of Color in Relation to Illumination—	L. T. Troland	Feb. 11	21
Part V—The Work of the National Bureau of Standards on the Establishment of Color Standards and Methods of Color Specifications—	I. G. Priest	Feb. 11	38
Part VI—Some Experiments on the Eye with Different Illuminants, Part I—	C. E. Ferree and G. Rand	Feb. 11	50
Economics in the Operation of Large Lighting Installations—	C. L. Law	Feb. 11	83
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Lighting Curtailment—	P. S. Millar	Mar. 20	111
The Value of Illuminating Engineering to the Gas Industry—	R. ff. Pierce	Mar. 20	170

TRANSACTIONS

OF THE

Illuminating Engineering Society

PART I -- SOCIETY AFFAIRS

VOL. XIII

JUNE 10, 1918

No. 4

COUNCIL NOTES.

ITEMS OF INTEREST FROM THE COUNCIL MEETING OF MAY 9, 1918.

Annual Convention Details.

The Committee on Time and Place presented to the Council a report recommending that no annual convention be held during the present fiscal year but favored a meeting of the Society on the evening of the annual meeting to be held in New York on October 10th. This is the usual date of the annual meeting at which the Report of the General Secretary to the Council is presented to the membership. Council decided that a one-day convention be held on that date, and the General Secretary was instructed to prepare a budget of the cost of such a convention.

Codes.

The Committee on Lighting Legislation through its Chairman presented a brief review of the activities of that committee with various State and Governmental officials in the preparation of lighting codes. Mention of the codes prepared with the co-operation of the

Society will be found in another column of this number.

Educational Institutions in War Service.

On April 11th Professor F. K. Richtmyer of Cornell University appeared before Council and explained the difficulties in retaining a full corps of instructors in engineering colleges at the time when the Government was making important demands on such institutions. President Stickney was requested to take up this question, as a result of which he reported at the May 9th meeting that he was in correspondence with Engineering Council and proposed to co-operate with them in handling this situation.

American Association of Engineers.

Mr. Wm. A. Durgin, Chairman of the Committee on Reciprocal Relations was requested by Council to appoint Messrs. James R. Cravath and Albert Scheible to attend the meeting of this association to be held in Chicago on May 14, 1918, and to report to Council on the proceedings.

New Members.

Upon recommendation of the Board of Examiners the following applicants were elected to membership:

One Sustaining Member.

GILLINDER & SONS, INC.
Tacony, Philadelphia, Pa.
Official Representative:
Edgar A. Gillinder.

WALLACE W. BRIGGS
District Manager,
Westinghouse Lamp Co.,
165 Broadway,
New York, N. Y.

Two Members.

JOHN YOUNG FLETCHER
Director,
General Electric Co., Ltd.,
67 Queen Victoria St.,
London, E. C. 4, England.

GEORGE HUMPFER, JR.
Electrician,
Strawbridge & Clothier,
8th and Market Sts.,
Philadelphia, Pa.

BEATRICE IRWIN
149 W. 57th St.,
New York, N. Y.

ARTHUR T. IRELAND
Supt. of Holder Stations,
The United Gas Improvement Co.,
Broad and Arch Sts.,
Philadelphia, Pa.

Three Transfers to Members.

HARRY ARCHER HORNOR
Consulting Engineer,
Hamilton Court, 39th and Chest-
nut Sts.,
Philadelphia, Pa.

CHARLES KADISON
N. Y. Gas & Electric Appliance Co.,
569 Broadway,
New York, N. Y.

WILLIAM KUNERTH
Associate Professor of Physics,
Iowa State College,
Ames, Iowa.

JEROME A. KOERBER
Display Manager,
Strawbridge & Clothier,
8th and Market Sts.,
Philadelphia, Pa.

JAMES D. LEE, JR.
Illuminating Engineer,
Westinghouse Lamp Co.,
Widener Bldg.,
Philadelphia, Pa.

PETER MCGLINN
Chief Engineer,
Strawbridge & Clothier,
8th and Market Sts.,
Philadelphia, Pa.

Thirteen Associate Members.

DANIEL M. ALTHOUSE
Electrician,
Strawbridge & Clothier,
8th and Market Sts.,
Philadelphia, Pa.

MITCHELL THOMAS MULROY
Salesman, Incandescent Lamps
Bryan-Marsh Division,
431 S. Dearborn St.,
Chicago, Ill.

RICHARD F. BANNER
Storekeeper of Incandescent Material
The United Gas Improvement Co.,
19th St. and Allegheny Ave.,
Philadelphia, Pa.

FOSTER B. TAYLOR
Special Inspector, Bureau of Illumi-
nating Engineering,
The New York Edison Co.,
130 E. 15th St.,
New York, N. Y.

SEYMOUR D. BENEDICT
State Dept. of Architecture,
Albany, N. Y.

RAYMOND S. WISE

Manager,
Kayser & Allman,
1522 Chestnut St.,
Philadelphia, Pa.

W. W. WOODRUFF

Purchasing Agent,
Strawbridge & Clothier,
8th and Market Sts.,
Philadelphia, Pa.

SECTION ACTIVITIES.

SCHEDULE OF MEETINGS

(Announced to the General Office prior to publication. Subject to revision.)

NEW YORK.

April 11—"Rockets and Illuminating Shells as Used in the Present War," by A. Bergman.

Report of Road Test of Headlighting Conditions.

May 9—"Industrial Plant Protection," by Edmund Leigh.

"An Instance of Industrial Lighting," by Bassett Jones.

PHILADELPHIA.

April 20—"The Progress of Illuminating Engineering During the Past Year," by F. E. Cady and R. ff. Pierce.

"The Relation of Light to Music," by Mary Hallock Greenewalt.

May 17—"Relation of Light to Health," by Dr. Chas. E. de M. Sajous.

CHICAGO.

April 18—"Mistakes in Engineering as Applied to Illumination," by F. J. Pearson.

May 27—"Regulation of Street Series Lamps in Practice," by F. A. Vaughn.

June 13—"The Training of a Lighting Salesman," by Charles A. Luther.

BOSTON.

May 21—"Plant Protection," by Edmund Leigh.

"Timely Aspects of Lighting," by M. Luckiesh.

NEW YORK.

Section Meeting of April 11, 1918.

At this meeting Mr. Bergman, Ordinance Engineering Corporation, gave an interesting talk on "Rockets and Illuminating Shells as Used in the Present War." He described the construction

and operation of rockets and the many types of illuminating shells for rifles, trench mortars, and naval guns which have been introduced during the present war. Their use in revealing enemy movements, also their novel use as a light barrage.

This talk was followed by a Report of Road Test of Headlighting Conditions, made under the Auspices of the Committee on Automobile Headlighting Specifications of the Illuminating Engineering Society and the Lighting Division of the Standards Committee of the Society of Automotive Engineers.

There were in attendance one hundred and fifty members and guests, forty of whom had attended the usual a la carte dinner at Healy's Restaurant. After the technical meeting the members and guests were entertained with a motion picture display, showing a cartoon of gas heating by the Consolidated Gas Company and one taken at a previous meeting at the Edison Studio, showing the various scenes during the meeting of the Society.

The Laboratories were thrown open for an inspection by the members and guests.

Section Meeting of May 9, 1918.

Mr. Edmund Leigh, Chief of Plant Protection Military Intelligence Bureau, Washington, D. C., presented a paper on "Industrial Plant Protection," and Mr. Bassett Jones, Consulting Engineer, New York, presented a paper on "An Instance of Industrial Lighting." One hundred and ten members and guests attended the meeting. The usual informal dinner was attended by twenty-five members.

PHILADELPHIA.

Section Meeting of April 20, 1918.

Imagine one side of the stage, at the

Engineers' Club, banked with palms, the center occupied by a lady at a Grand piano against a back-ground of white drapery, while varying shades of color played over the scene and you have an idea of the closing act of the April meeting of the Philadelphia Section.

The room was filled when Chairman Forstall called the meeting to order, promptly at eight o'clock. The paper of the evening was on "The Progress of Illuminating Engineering During the Past Year," by Mr. F. E. Cady of the National Lamp Works of Cleveland, Ohio, and Mr. R. H. Pierce of the Welsbach Company. Mr. Pierce spoke of the progress in gas manufacture and lighting, the principle development, from an economic standpoint, being an apparatus which has been devised for generating gas from the millions of tons of straw which are annually burned in Canada in order to clear the ground.

Mr. Cady spoke of electrical illumination, mentioning many different forms of lamps and devices which have been recently placed upon the market. His talk was illustrated by lantern slides as well as by an extensive exhibition of the devices referred to which had been collected by the Exhibition Committee under Mr. C. J. Firth.

Following these speakers Mrs. Mary Hallock Greenewalt gave a talk on "The Relation of Light to Music." She spoke of the effect of light in nature on birds and flowers and compared the various colors with the tones in music. She illustrated her point by playing Beethoven's "Moonlight Sonata," with an accompaniment of blueish light which increased and decreased with the music. Then playing one of De Bussy's pieces, she was enveloped in varying shades of color which were intended to give a visible expression to the musical notes.

Preceding the meeting the usual din-

ner was held in the club, which was attended by twenty-eight members and guests. Chairman Forstall sat at the head of the table, while among those present were Mr. F. E. Cady of Cleveland; Mr. Preston S. Millar of New York; Mr. Wm. H. Beck of Baltimore, as well as ex-Presidents Wm. J. Serrill and C. O. Bond.

Section Meeting of May 17, 1918.

Twenty-four members and guests attended the dinner, while approximately sixty persons attended the final meeting of the season.

On account of unexpected absence Mr. H. Lyon was unable to give his talk on the "Fundamentals of Illuminating Engineering," as announced. Dr. Chas. E. de M. Sajous delivered a paper on "Relation of Light to Health." His paper was illustrated by picture projections, showing various stages of diseases which had been cured by exposure to sunlight under the proper conditions. He also showed pictures of patients, with a minimum of clothing, apparently enjoying the outdoor sunlight treatment amid the snow-covered mountains of Switzerland. Even though the paper was essentially a medical subject there was considerable discussion, showing the versatility of the audience.

Reciprocal votes of thanks were given by the retiring Chairman, Mr. Walton Forstall, for the assistance which he had received from the managers and various committees, and also by the members to the Chairman for his successful administration.

CHICAGO.

Section Meeting of April 18, 1918.

The meeting was held in the Western Society of Engineers' Auditorium at which a paper by Frederick J. Pearson

on "Mistakes in Engineering as Applied to Illumination," was presented. The paper was discussed by Messrs. J. R. Cravath, F. A. Watkins, N. C. Spake, J. J. Ryan, O. L. Johnson, F. H. Bernhardt, and I. H. Pierce. About thirty members and guests attended the meeting.

NEW ENGLAND.

Section Meeting of May 21, 1918.

The last meeting of the season was held at the Engineers' Club of Boston. The papers included "Plant Protection" by Edmund Leigh, Chief of Plant Protection, Military Intelligence Bureau, Washington, D. C., "Timely Aspects of Lighting" by Mr. M. Luckiesh, and "Different Types of Flood Lights" by Mr. H. H. Magdsick, National Lamp Works, Nela Park, Ohio. The speakers were introduced by Chairman Wallace. Mr. Stickney gave a general talk on the objects and policies of the Society.

Mr. Leigh gave a practical talk on plant protection, bringing out many interesting and important points on the subject, emphasizing the importance of good fencing, good lighting and efficient watch service. Mr. Luckiesh, as usual, gave a most interesting talk. Mr. Magdsick aided by lantern slides and explained the different types of flood lights.

The appropriateness of the subjects probably accounts for the large attendance, 85 members and 35 other interested persons being present. After the talks a buffet luncheon was served.

NEWS ITEMS.

Lighting Code of the Divisional Committee on Lighting.

A pamphlet officially entitled "Welfare Work Series, No. 3, 1918; Code of Lighting Factories, Mills and Other Work Places" has been prepared by the Divisional Committee on Lighting of the Committee on Labor, Advisory Commission, Council of National Defense, the members of which were nominated by the Illuminating Engineering Society at

the request of the Committee on Labor. This code has been published and is being distributed in pamphlet form by the Committee on Labor, Washington, D. C.

Lighting Code for Federal Industrial Establishments.

The United States Employees' Compensation Commission has issued a compendium of Federal Standards for Building Construction as prepared by the Bureau of Standards in conjunction with the Safety Engineers of Federal Industrial Establishments. These standards include a lighting code for which the I. E. S. is given credit in the following paragraph:

"A discussion of the elements of satisfactory artificial lighting will be found in the Industrial Lighting Code of the Illuminating Engineering Society upon the provisions of which these rules are based."

Pennsylvania Industrial Lighting Code.

The Industrial Board of the Department of Labor and Industry of Pennsylvania adopted a lighting code on April 13, 1916, which became operative on June 1 of that year. This code was revised February 13, 1918 and is now issued in Vol. I, No. 16, of the Safety Standards of the Industrial Board.

The first edition of the Pennsylvania lighting code consisted of only two pages containing rules. The revised edition contains besides the rules, an appendix giving general information and suggestions relating to lighting, covering thirty pages.

Credit is given to the I. E. S. in the last paragraph of the appendix as follows:

"The Department of Labor and Industry is indebted to the Illumi-

nating Engineering Society for their co-operation and assistance in the preparation of this lighting code and the provisions of this code meet with their approval."

The principal revision was made in the rule relating to the intensity of light. The revised rules in full appear in this number of the TRANSACTIONS.

Committee on Nomenclature and Standards.

The meeting of the Committee on Nomenclature and Standards was held on May 9th in New York. As a standard value for the mechanical equivalent of light the figure 0.0015 watt per lumen is recommended. A sub-committee was appointed to prepare a recommendation regarding the proper crossing point of spectrophotometric curves.

Engineering Council Activities.

The following brief sentences summarize the activities of Engineering Council as presented in a bulletin issued by the Council under date of April 20, 1918:

The American Engineering Service Committee has been very active in supplying trained men for the Army and Navy and in aiding in enlistments in the aviation, tank and signal corps. The War Committee of Technical Societies continues its functions of selecting worthy inventions from the many submitted for use by the War and Navy Departments. The Public Affairs Committee passed a resolution urging authorities of engineering schools "to direct all their resources to the winning of the War," particularly recommending that instructors be relieved of routine duties in order further to give their time to instruction of men learning war work. A Water Conservation Committee was created to give effective action to questions on the utilization and conservation of water supplies for all public purposes. A Military Aid Committee was appointed to aid the Government in the supplying and recruiting of special engineering units. The question of licensing and registering engineers under state laws was referred to the Public Affairs Committee. The personnel of the Patents Committee, organized to investigate reforms in the United States patent system,

was enlarged. A special committee was appointed to investigate the status of *industrial efficiency* and to determine the causes for a gain or loss.

Opportunities with Bureau of Mines.

The Bureau of Mines, American University, Washington, D. C., wishes the services of men trained in the following occupations. Communications should be addressed to the Bureau of Mines:

Bacteriologists
Biologists
Chemists, Inorganic
Chemists, Organic
Chemists, Physical
Chemists, Electrochemical Engineers
Draftsmen
Electrical Engineers
Instrument Makers
Laboratory Assistants
Laborers
Machinists
Physiologists
Plumbers
Steamfitters
Stenographers
Skilled labor of various kinds.

Lectures on Factory Lighting.

A very interesting series of lectures on the Code of Lighting Factories, Mills and Other Work Places was afforded to the State Factory Inspectors of the States of Pennsylvania and New Jersey at the University of Pennsylvania, on April 25 and May 9, 1918. Those who delivered addresses and lectures were Dr. Edgar F. Smith, Provost, University of Pennsylvania; Dr. Harold Pender, Professor-in-Charge, Department of Electrical Engineering, University of Pennsylvania; Acting Commissioner Lew R. Palmer, Department of Labor and Industry, Pennsylvania; Commissioner L. T. Bryant, Department of Labor, New Jersey; Mr. G. H. Stickney, Professor C. E. Clewell, and Wm.

J. Serrill. "Specification of Quantity of Light," "Relations of Glare to Factory Lighting," and "Distribution of Light in Factory Spaces," were the lectures delivered by Professor C. E. Clewell.

D. C. and W. B. Jackson, Consulting Engineers, Boston and Chicago, have circulated notices to the effect that they will close their offices and suspend business for the duration of the war as soon as the various pieces of work with which they are occupied can be completed. This action has been taken on account of the fact that two members of the firm have gone into National Service and the third member expects to do so at an early date. It is the expectation that this firm will resume business after the close of the war.

GENERAL OFFICE.

Sell Your Transactions.

Members can aid the Society by sending in extra copies of back numbers of the TRANSACTIONS as listed below. For each of these copies received at the General Office in good condition, the Society will remit fifty cents (50¢).

Vol. I—Nos. 1, 2, 3, 4, 5, 6, 7.

Vol. II—Nos. 1, 2, 3, 4.

Vol. III—Nos. 1, 4, 5.

Vol. VIII—Nos. 1, 2, 3, 4.

Such copies as may be received in this way will be placed for permanent reference on the shelves of libraries throughout the country. If the library in your neighborhood does not have the TRANSACTIONS please advise the General Office.

ILLUMINATION INDEX.

Prepared by the Committee on Progress.

An index of references to books, papers, editorials, news and abstracts on illuminating engineering and allied subjects. This index is arranged alphabetically according to the names of the reference publications. The references are then given in order of the date of publication. Important references not appearing herein should be called to the attention of the Illuminating Engineering Society, 29 W. 39th St., New York, N. Y.

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Industrial Lighting a Field of Wide
Opportunity that Presents No
Obstacle that Energy and Intelli-
gence Cannot Surmount—

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American Journal of Ophthalmology

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Perimetric Study and General Of-
fice Use—

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Stereoscopic and Perspective Vision—
Endurance of the Eye with Different
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Astrophysical Journal

Generalization of the Problem of the
Rotation of Prisms Producing
Constant Deviation by Two Re-
fractions and One Internal Reflec-
tion—

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The Visibility of Radiation in the Blue
End of the Visible Spectrum—

L. W. Hartman	Mar.	83
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Electrician (London, Eng.)

Filaments for Glow Lamps—
Correction Factors for the Pentane
Lamp (Note)—

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The Lighting of the Great Barrier
Reef (Note)—

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Electrical Engineering

First Town Lighted by Electricity—

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Electrical Review (London, Eng.)

Methods of Directing and Concentrat-
ing Light—

Lt. Com. H. T. Harrison, R. N. V. R.	Mar. 8	222
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Experiments on Electroculture—

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An Electrically Illuminated Fountain—

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Interesting Electrical Features of Chicago's Evangelistic Tabernacle—	News Item	Apr. 27 716
Common Sense Found Very Essential in Illumination—	News Item	Apr. 27 722

Electrical World

Changing Aspects of Factory Lighting Legislation—	C. E. Clewell	Mar. 30 665
Specifications for Factory Lighting—	Editorial	Mar. 30 655
Lighting Curtailment in the Industries—	A. L. Powell	Apr. 6 709
Conservation Versus Efficiency in Lighting—	Editorial	Apr. 6 705
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Gas-Filled Lamps for the "Movies"—	Editorial	Apr. 13 758
Effect of Daylight Saving—	News Item	Apr. 20 833
Recent Developments in Marine Lighting (Abstract from London Engineer, Mar. 8, 1918)—		Apr. 20 834
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Stimulating Production of Good Lighting—	Editorial	Apr. 27 862
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The Effect of Daylight Saving on Load—	News Item	May 11 972

Gas Record

Aspect of Factory Lighting—	R. ff. Pierce	Apr. 10 238
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General Electric Review

Standardized Flexible Distributing Systems in Industrial Plants. Part II, Application—	Bassett Jones	Apr. 285
Fundamentals of Illumination Design Part I; Fundamental Concepts—	Ward Harrison	May 353

Illuminating Engineer (London, Eng.)

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Daylight Saving and Central Station Load—	W. G. Vincent, Jr.	May 1	446
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Electric Lighting of Ecclesiastical Buildings—	W. Wilson	Mar.	193
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Inefficiency of Carbon and Gem Lamps—	News Item	Apr.	215
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The Behavior of Scattering Media in Fully Diffused Light—	F. F. Renwick and B. V. Storr	Mar. 1	222
Ultra-violet Transparency of the Lower Atmosphere, and Its Relative Poverty in Ozone—	R. J. Strutt	Apr. 2	260

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Importance of Correct Lighting in the Shop—

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Chicago and North Western Car Lighting Equipment—

News Item Apr. 102

**Science Abstracts, Sections A and B
(London, Eng.)**

Double-arc Lamps for Low-frequency Three-phase Working (Abstract from Rev. Gen. d'El. 2, p. 975, Dec. 22, 1917)—

A. Blondel (Sec. B) Feb. 78

Tungsten Filaments (Abstract from Elektrot. u. Maschinenbau 35, p. 501, Oct. 21, 1917)—

Schröter (Sec. B) Feb. 79

Humidity Correction Factor for Pentane Lamp (Abstract from Electro-Techn. Laborat., Dept. of Communications, Tokyo, Oct., 1917)—

K. Takatsu and M. Tanaka Mar. 106

The Constant O in the Stefan-Boltzmann Law (Abstract from N. Cimento, 13, p. 142, Feb., 1917)—

M. Kahanowicz Mar. 120

Further Investigation with Arcs Under Pressure (Abstract from Elek. Zeits. 38, p. 573, Dec. 6, 1917)—

W. Mathiesen Mar. 122

Siemens and Halske Globe Photometer (Abstract from Elekt. Zeits. 38, p. 605, Dec. 27, 1917)—

R. v. Voss Mar. 124

Scientific American Supplement

Light Projection—

C. A. B. Halvorson and R. B. Hussey Apr. 20 254

Scientific Monthly

The Research Couplet; Research in Pure Science and Industrial Research—

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Code of Lighting School Buildings—

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The General Level of Illumination Intensities in Large Department Stores of New York City—

W. F. Little and J. F. Dick Apr. 30 201

An Indirect Lighting System in a Textile Plant—

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Abstract—An Aspect of Light, Shade, and Color in Modern Warfare—

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TRANSACTIONS

OF THE

Illuminating Engineering Society

PART I -- SOCIETY AFFAIRS

VOL. XIII

JULY 20, 1918

No. 5

COUNCIL NOTES.

ITEMS OF INTEREST FROM THE COUNCIL MEETING OF JUNE 13, 1918.

Annual Convention Details.

At the last meeting of the Council the recommendations of the Committee on Time and Place were approved. These recommendations called for the holding of a one-day convention on the day of the annual meeting of the Society, October 10, 1918, in New York. This will be strictly a war convention; only those matters having to do directly with lighting and its relation to the successful outcome of the war will be discussed. There will be no entertainment features of any kind provided. A convention committee will be appointed at the next meeting of the Executive Committee of the Council, which will be held on July 10th.

Educational Institutions in War Service.

At the last meeting of the Council the President read resolutions to the Government that had been prepared by Engineering Council urging that the teaching staffs of all universities and colleges should not be too greatly depleted through enlistments and the draft,

in order that the country might not be deprived in the future of technically trained engineers. Council endorsed these resolutions.

New Members.

Upon recommendation of the Board of Examiners the following applicants were elected to membership:

Two Members.

A. BERGMAN

Chief Engineer,
Ordnance Engineering Corp.,
120 Broadway,
New York, N. Y.

JAMES W. WEST

Plant Engineer,
The Forbes Lithograph Mfg. Co.,
Chelsea, Mass.

Two Transfers to Membership.

A. R. ACHESON

Consulting Engineer,
216 City Hall,
Syracuse, N. Y.

LAWRENCE L. STRAUSS

Electrical Contractor and Engineer,
72 West 125th St.,
New York, N. Y.

Nineteen Associate Members.

R. L. BEACH

Edison Lamp Works,
Harrison, N. J.

PETER A. COGHLIN
Economy Electric Co.,
22 Foster St.,
Worcester, Mass.

CHARLES DESHLER
Edison Lamp Works,
Harrison, N. J.

JOHN E. EDWARDES
Electrical Contractor,
The E. & M. Electric Co.,
35 Hartford St.,
Boston, Mass.

H. J. FLAHERTY
Assistant Engineer Street Lighting
Dept.,
General Electric Co.,
West Lynn, Mass.

CARL T. FULLER
Incandescent Lamp Engineer,
Edison Lamp Works,
Harrison, N. J.

G. H. HAMOND
Salesman,
Westinghouse Lamp Co.,
10 High St.,
Boston, Mass.

FRED P. KELLEY
Salesman and Special Representative,
Warner Lenz Co.,
914 S. Michigan Ave.,
Chicago, Ill.

J. T. KERENS
Incandescent Lamp Specialist,
Edison Lamp Works,
84 State St.,
Boston, Mass.

A. H. MAGNUSON
Chief Electrician,
Graton & Knight Mfg. Co.,
Franklin St.,
Worcester, Mass.

EUGENE F. MCCARTHY
General Electric Co.,
West Lynn, Mass.

JULIUS NOVEMBER
Draughtsman,
Westinghouse Lamp Co.,
Bloomfield, N. J.

HARRY H. NEEDHAM
Incandescent Lamp Engineer,
Edison Lamp Works,
Harrison, N. J.

J. C. PARKER
Professor of Electrical Engineering,
University of Michigan,
Ann Arbor, Mich.

C. E. PARKHURST
Designer of Lighting Fixtures and
Architectural Metal Work,
Gorham Co.,
386 Fifth Ave.,
New York, N. Y.

E. ALFRED RENDALL
Illuminating Engineer,
Central Hudson Gas & Electric Co.,
50 Market St.,
Poughkeepsie, N. Y.

MILTON D. RILEY
Specialist on Illuminating Devices,
Western Electric Co., Inc.,
585 Summer St.,
Boston, Mass.

H. A. TULLIDGE
Manager, Incandescent Lamp Dept.,
Union Electric Co.,
933 Liberty Ave.,
Pittsburgh, Pa.

HOWARD I. WOOD
Incandescent Lamp Engineer,
Edison Lamp Works,
Harrison, N. J.

New Council and Section Officers.

Council received the report submitted by the Committee of Tellers and confirmed the election of the Council and Section officers for the fiscal year 1918-1919. Following is a full list of Council

and Section officers who will act in their respective official offices for the year 1918-19. (Those names in bold face type indicate newly elected officers.)

OFFICERS AND COUNCIL, 1918-1919.

President:

George A. Hoadley

Junior Past Presidents:

William J. Serrill

George H. Stickney

Vice-Presidents:

Otis L. Johnson

H. K. Morrison

W. Greeley Hoyt

C. E. Stephens

H. A. Hornor

General Secretary:

Clarence L. Law

Treasurer:

L. B. Marks

Directors:

C. A. Luther

D. McFarlan Moore

P. G. Nutting

R. ff. Pierce

S. C. Rogers

P. S. Young

John C. D. Clark

Evan J. Edwards

James J. Kirk

SECTION OFFICERS, 1918-1919.

New York Section:

Chairman:

F. M. Feiker

Secretary:

L. C. Porter

Managers:

W. J. Clark

John P. Hanlan

L. J. Lewinson

G. W. Magalhaes

John P. Radcliffe

New England Section:

Chairman:

H. F. Wallace

Secretary:

Horace W. Jordan

Managers:

G. N. Chamberlin

John C. D. Clark

Raymond A. Fancy

F. A. Gallagher, Jr.

A. F. Nelson

Philadelphia Section:

Chairman:

James D. Lee, Jr.

Secretary:

H. B. Andersen

Managers:

C. E. Clewell

Washington Devereux

R. B. Duncan

W. L. Robertson

N. Wiley Thomas

Chicago Section:

Chairman:

A. O. Dicker

Secretary:

Frederic A. DeLay

Managers:

F. Fowle

James J. Kirk

A. H. Meyer

W. W. Soffe

F. A. Watkins

SECTION ACTIVITIES.

PHILADELPHIA.

Section Meeting of April 20, 1918— Correction.

In Volume XIII, No. 4 TRANSACTIONS, appeared a brief report of the above meeting. Mrs. Mary Hallock-Greenewalt who gave a recital on the "Relation of Light to Music" calls to our attention the following statement which more accurately presents the aspects of the presentation:

"The idea is rather to invest light and its color powers with that sensitiveness of expression which could allow it to occupy the center of the stage parallel to, and in sympathetic union with any other art, no matter how fine, transitory or subtle its succession."

"As a matter of fact, light turned into a fine art has been linked so 'here and there' with music because music happened to be the vocation of the individual launching the idea, first publicly on April 15, 1911, and naturally discussed sometime sooner."

Mrs. Greenewalt further states that

"there is no more organic, inherent or visualizing relation between light and music than there is between light and any expressed feeling. I am glad it was saved for the most spiritual and subtle medium of expressing music first."

CHICAGO.

Section Meeting of May 27, 1918.

A joint meeting of this Section with the Western Society of Engineers and American Institute of Electrical Engineers was held at the meeting room of the Western Society of Engineers of Chicago. Mr. F. A. Vaughn of Vaughn & Meyer, Consulting Engineers of Milwaukee, presented a paper on "Regulation of Street Series Lamps" which

was discussed by Messrs. F. H. Bernhard, L. M. Hecker, P. S. Millar, J. J. Ryan and E. M. Tompkins. Fifty-three members and guests attended this meeting which was the last meeting of the regular program of this Section for the present season.

Section Meeting of June 13, 1918.

A very interesting meeting was held by this Section of the Society at which a paper was presented by Mr. Charles A. Luther, of the Peoples Gas Light & Coke Company, on the "Training of a Lighting Salesman." The paper was discussed by Messrs. E. H. Freeman, Albert Scheible, Frederic A. DeLay, George H. Severn, Alfred O. Dicker and Terrell Croft.

NEWS ITEM.

Committee on Automobile Headlighting Specifications.

The Committee on Automobile Headlighting Specifications held a meeting on the 3rd, 4th and 5th of June, and in connection with this meeting conducted certain road tests of automobile headlights. The specific and immediate purpose of the meeting was to prepare for the Secretary of State of the State of New York a set of specifications under which headlighting devices might be subjected to laboratory tests to determine their conformity to the recently amended New York State Highway Law. Mr. G. B. Nichols, Chief Engineer of the State Architect's Office in Albany, and Local Representative of the Society in Albany, represented the Secretary of State at this meeting. The Lighting Division of the Standards Committee of the Society of Automotive

Engineers joined with the I. E. S. Committee in this meeting, and the I. E. S. Committee on Lighting Legislation was represented by its Chairman, Mr. L. B. Marks. The points in the New York State Highway Law which could be covered by tests are briefly as follows:

"The front lights shall be so arranged, adjusted and operated as to avoid dangerous glare or dazzle, and so that no dangerous or dazzling light projected to the left of the axis of the vehicle when measured 75 ft. or more ahead of the lamps, shall rise above 42 in. on the level surface on which the vehicle stands."

"Front lights shall be sufficient to reveal any person, vehicle or substantial object on the road straight ahead of such motor vehicle for a distance of at least 200 feet."

As the result of the consideration of the various experimental data which were made available by these and by previous tests, the Committee formulated a specification for the laboratory test of headlighting devices which was submitted to the Secretary of State, and which after a public hearing held by him on June 25th, was formally adopted. Briefly, this specification states that the intent of the New York State Highway Law is deemed to be complied with if the following conditions are fulfilled:

(a) Any pair of headlamps under the conditions of use must produce a light which, when measured on a level surface on which the vehicle stands at a distance of 200 ft. directly in front of the car and at some point between the said level surface and a point 42 in. above this surface, is not less than 1,200 apparent candlepower.

(b) Any pair of headlamps under the conditions of use shall produce

a light which, when measured at a distance of 100 feet directly in front of the car, and at a height of 60 in. above the level surface on which the vehicle stands, does not exceed 2,400 apparent candlepower, nor shall this value be exceeded at a greater height than 60 in.

(c) Any pair of headlamps under the conditions of use shall produce a light which, when measured at a distance of 100 ft. ahead of the car, and 7 ft. or more to the left of the axis of the same, and at a height 60 in. or more above the level surface on which the vehicle stands, does not exceed 800 apparent candlepower.

It also lays down with considerable elaboration the tests which must be conducted in the laboratory to determine whether any given device will produce the results which are contemplated in the above interpretation of the law.

The method by which headlight performance is specified is believed to be quite a novel one, and although the numerical limits imposed are very lenient, and are based upon the present state of the headlighting art, having in view the large number of cars already provided with more or less satisfactory devices, it is hoped that this method of specification taken in connection with laboratory tests should result in a gradual but marked improvement in road conditions.

Engineering Council Activities.

The following brief sentences summarize the activities of Engineering Council as presented in a bulletin by the Council under date of June 24, 1918:

The organization meeting of Engineering Council was held June 27, 1917, and

the meeting held on June 20, 1918, completes the first year of the Council's activities. During the year the Council has done much to perfect its organization, to strengthen its relationships with the societies and the Government and has accomplished much useful work. In order to have more intimate contact with the branches of the national societies and other local organizations of engineers, the Secretary of Engineering Council is planning, during July and August, to visit the following cities in which there are important groups of engineers: Milwaukee, Denver, Salt Lake City, Reno, San Francisco, Portland, Seattle, Spokane, Butte, St. Paul, Minneapolis, Duluth, Detroit, Cleveland and Buffalo. In May a trip was made to Chicago, St. Louis and Pittsburgh with pleasant and satisfactory results.

Protective Lighting.

A pamphlet on "Protective Lighting," material for which was prepared for the Government by the Illuminating Engineering Society's Committee on War Service, has been printed at the Government Printing Office in Washington. Copies of this may be obtained upon application to Major-General J. McI. Carter, Chief Militia Bureau, Washington, D. C.

Under date of April 8th, the following communication was sent by the United States Fuel Administrator to all County Administrators:

"To even the most casual observer it is evident that a large saving of coal can be effected by a more judicious system of street lighting. In many places lamps are lighted long before dark—even before sundown—and kept burning after daybreak. This should be stopped; the lighting at night delayed, and the lamps extinguished early in the morning.

"You will frequently find certain streets or certain areas of cities flooded with light. Great 'White Ways' and a similar prodigal use of light may be all right in peace times, but in war times such excessive lighting

should be eliminated. Use no more lights than will reasonably well light your streets—don't burn light for display.

"In the early development of street lighting, when the moon shone brightly, street lamps were not lighted. It might not be a bad idea to again adopt this scheme. The use of sufficient light is to be encouraged, but its waste discouraged.

"When inefficient lamps are in use, substitute the better ones—you will get more light with a less consumption of coal.

"Street lighting contracts usually require that lamps burn a definite number of hours per annum or that they be lighted at or before sunset and extinguished about sunrise. In such cases a readjustment or contract requirements will be necessary. It is suggested by the Fuel Administration that you get in touch with all political subdivisions, cities, towns, etc., within your jurisdiction having any such contracts and require them to arrange with the various companies for such modification of these contracts as will result in the most advantageous consumption of coal. You might require all new schedules of lighting to be approved by you or by your State Fuel Administrator.

"For your information, we might add that this office is considering the issuance of an order prohibiting outside display lighting other than during the hours of street lighting.

"Very truly yours,

"U. S. FUEL ADMINISTRATOR.

"(Signed) P. B. NOYES,
"Director of Conservation."

A Council on Eyesight.

(Excerpt from *The Electrician* (London), May 10, 1918, page 22.)

Following a meeting of ophthalmic surgeons, recently held at the house of the Royal Society of Medicine, it has been decided to set up a standing advisory council on all matters relating to eyesight. The acting and past presidents of the Ophthalmological Society and of the Section of Ophthalmology of the Royal Society of Medicine, will be permanent members, and the Council will have power to co-opt others interested in various aspects of the problem.

Code of Lighting for Factories, Mills and Other Work Places.

The State of New Jersey has officially issued in pamphlet form copies of the above Code. Mention is made in the last paragraph of this pamphlet that:

The Department of Labor is indebted to the I. E. S. for their co-operation and assistance in the preparation of this lighting Code and the provisions of this Code meet with their approval.

A limited number of copies of this Code are at the General Office and will be issued upon request.

I. E. S. WAR NOTES.

Naval Aircraft Factory.

The Naval Aircraft Factory of the Navy Yard, Philadelphia, Pa., has forwarded to this office a letter advising that technically trained men are urgently needed at this factory principally for drafting work, assembling of materials, design of machine tools, erection and inspection. Communications should be addressed to J. H. Willits, Employment Superintendent, U. S. Naval Aircraft Factory, Philadelphia, Pa.

Red Cross Institute for Crippled and Disabled Men.

The above organization recently issued a letter under date of May 21st addressed to the editors of various technical journals throughout the country, urging employers to consider the advisability of placing crippled or disabled soldiers and sailors in positions which their future would depend upon initiative and ability. The presentation decried employment of such men in positions which would not provide opportunity for advancement. The fol-

lowing striking paragraph presents suggestions to employees:

To study the jobs under his jurisdiction to determine what positions might be satisfactorily held by cripples. To give the cripples preference for these jobs. To consider thoughtfully the applications of disabled men for employment, bearing in mind the importance of utilizing to as great an extent as possible labor which would otherwise be unproductive. To do the returned soldier the honor of offering him real employment, rather than proffering him the ignominy of a charity job.

GENERAL OFFICE.

Resignation of the Assistant Secretary.

Mr. C. D. Fawcett, who has acted in the capacity of Assistant Secretary of our Society for the past two years, has tendered his resignation, which took effect June 22nd. He is associated with the electrical engineering staff of Monks & Johnson, consulting engineers and architects, engaged in the Emergency Fleet Corporation to design certain ship yards throughout the country. It is a matter of regret to have lost the services of Mr. Fawcett in the General Office because of his conscientious work while he was associated with us. This feeling, however, is ameliorated because the character of his new position will mean a further service to the Government.

Sell Your Extra Copies of the Transactions.

Members can aid the Society by sending in extra copies of back numbers of the TRANSACTIONS as listed below. For each of these copies received at the General Office in good condition, the Society will remit fifty cents (50¢).

Vol. I—Nos. 1, 2, 3, 4, 5, 6, 7.

Vol. II—Nos. 1, 2, 3, 4, 8.

Vol. III—Nos. 1, 2, 3.

- Vol. VI—No. 4.
 Vol. VII—No. 3.
 Vol. VIII—Nos. 1, 2, 3, 4.
 Vol. IX—Nos. 2, 3, 5, 7.
 Vol. X—No. 1.
 Vol. XI—No. 9.

OBITUARY.

Mr. James Thomas Maxwell, General Agent of the Philadelphia Electric Company and an active member of the Illuminating Engineering Society, died at his home in Woodbury, N. J., on May 27th, at the age of 68 years.

Mr. Maxwell's association with the Society commenced as Secretary of the Organizing Committee of the Philadelphia Section in 1906. When the second convention of the Society was held in Philadelphia in September, 1908, he was the Chairman of the Finance Committee, a member of the Reception and Entertainment Committee and Treasurer of the convention, and to him was largely due its success and the pleasant memories of those who attended that occa-

sion. He was Chairman of the Philadelphia Section, 1909-10, and Vice-President of the Society representing that Section in 1911-12.

Mr. Maxwell attended most of the conventions of the Society and, although he did not take an active part in the discussions he was always interested in the proceedings, as well as in the meetings of the local section. Upon these conventions he always looked back with pleasure, as was shown by the various photographs he had upon the walls of his office of the groups of members taken at the various places.

Leaving New York early in life Mr. Maxwell moved to Philadelphia where he engaged in telegraphy, afterwards becoming manager of the Bankers and Merchants Telegraph Company, a local institution which did considerable business in its day. In September, 1888, he entered the services of the Edison Electric Light Company and became the General Agent of the Philadelphia Electric Company after the consolidation of the various electric light companies in that city.

ILLUMINATION INDEX.

Prepared by the Committee on Progress.

An index of references to books, papers, editorials, news and abstracts on illuminating engineering and allied subjects. This index is arranged alphabetically according to the names of the reference publications. The references are then given in order of the date of publication. Important references not appearing herein should be called to the attention of the Illuminating Engineering Society, 29 W. 39th St., New York, N. Y.

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The Efficiency of Light-Production in Organisms—	T. Peczalski	May 710
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Color in Illumination (Abstract from Engineers' Club of Philadelphia, April, 1918)—	Beatrice Irwin	June 520
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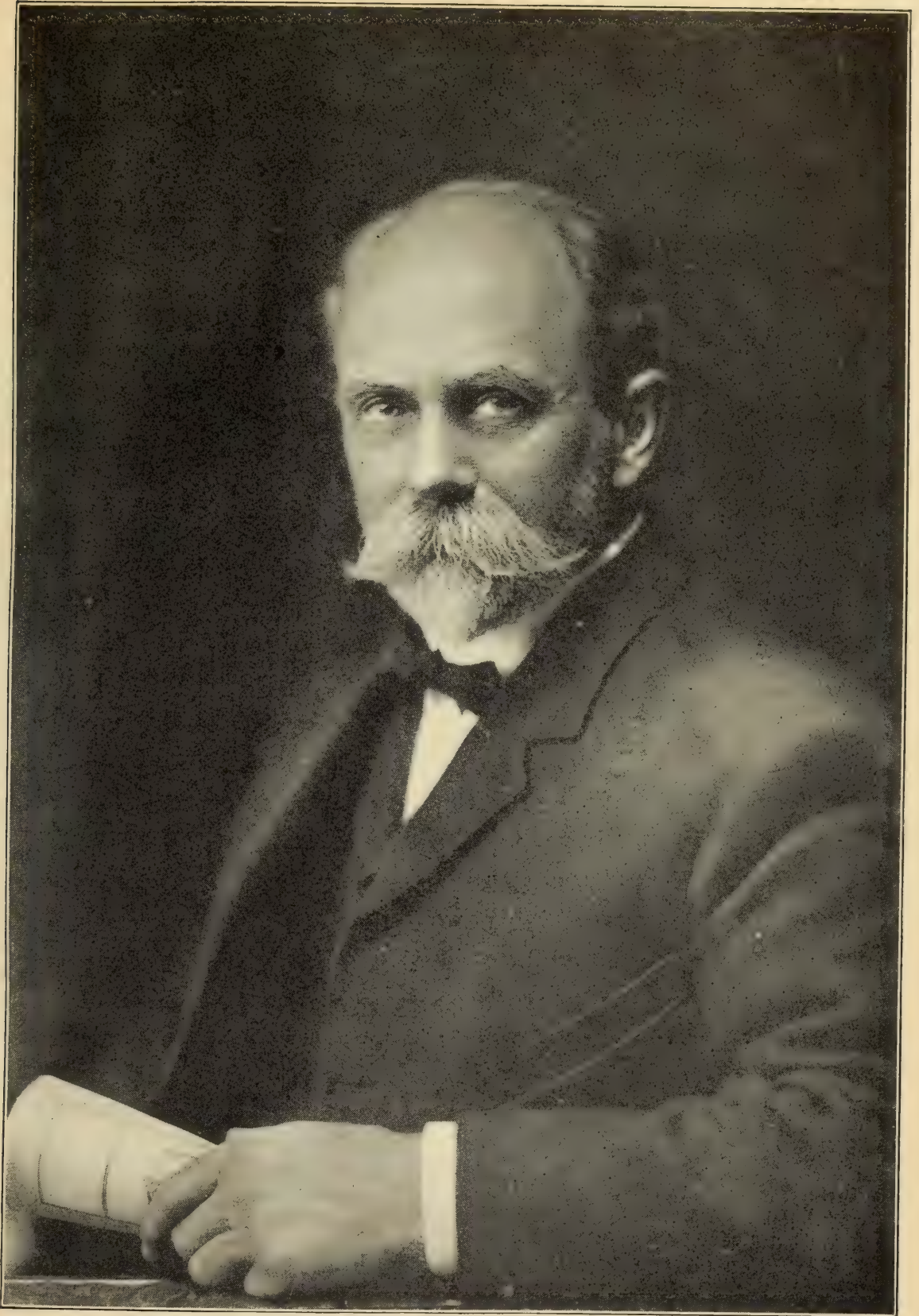
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DR. GEORGE A. HOADLEY

President-Elect of the Illuminating Engineering Society for the Fiscal Year 1918-1919.

(Biography on page 66 of Part I.)

TRANSACTIONS

OF THE

Illuminating Engineering Society

PART I -- SOCIETY AFFAIRS

VOL. XIII

AUGUST 30, 1918

No. 6

COUNCIL NOTES.

ITEMS OF INTEREST FROM THE MEETING OF THE COUNCIL EXECUTIVE COMMITTEE HELD ON JULY 10, 1918.

1918 Convention.

Mr. D. McFarlan Moore was appointed Chairman of the 1918 Convention Committee. Pending a meeting of the committee yet to be appointed, no details of the convention have as yet been formulated. The convention, however, will be along the lines of the importance of lighting during the present war period.

Council Meetings Suspended.

The last regular meeting of the Council preceding the summer session was held on June 13th. The present Council and the newly elected Council for the fiscal year of 1918-1919 will meet in joint session on October 10, 1918. At this time the formal transfer of administrations occurs. During the summer months the Council Executive Committee consisting of five officers of the Council, is authorized to meet and transact such business as may be necessary.

New Members.

Upon recommendation of the Board

of Examiners the following applicants were elected to membership:

One Member.

MARSHALL W. HANKS
Standards Manager,
Society of Automotive Engineers,
Inc.,
29 West 39th St.,
New York, N. Y.

Two Associate Members.

FREDERICK W. BLISS
Lamp Salesman,
Edison Lamp Works,
1012 Turks Head Bldg.,
Providence, R. I.
KEYIH SOOCHIN YUEN
American General Electric Edison
Corp. of China,
Shanghai, China.

Committee on Sky Brightness.

Through the interest shown in the subject of daylighting by engineering editors of the *American Architect* and the *Metal Worker*, who had come to the Society's headquarters for information on the subject, the question of the formation of a committee to investigate daylighting was presented to Council. According to Constitutional requirements, a letter ballot was submitted to the members of the Council, as a result of which a committee was appointed and Mr. William F. Little was made Chairman.

Resolutions Regarding the Death of Mr. James T. Maxwell.

The following resolution was adopted and ordered incorporated in the regular minutes of the Society:

Resolved, That the Executive Committee of the Society having just learned with deep sorrow of the death of our friend and co-worker, James T. Maxwell, desires to place on record our appreciation of the ability and devotion which he has always shown and served in the interest of the Society. During the period of his connections with the Society he served as a valuable officer, having acted in the capacity of Chairman of the Philadelphia Section from 1909-10, and Vice-President representing that Section from 1911-12. We deeply deplore the loss and offer our profound sympathy and sincere condolence to his family at this time. He gained the respect of every one who knew him, or came in contact with him in any way, and his memory will remain dear to us all;

Resolved, That this tribute be recorded on the minutes of the Society and a copy be forwarded to his family.

in 1913, is the latest work of Dr. Hoadley.

He is a charter member of the American Physical Society, a Fellow of the American Physical Society, a Fellow of the American Association for the Advancement of Science, Associate Member of the American Institute of Electrical Engineers. He was Chairman of the Philadelphia Section of the A. I. E. E. for one year, and a member of the Board of Managers of the Franklin Institute.

Prior to his election as President, Dr. Hoadley held the following offices in the Illuminating Engineering Society:

Chairman Philadelphia Section 1913.

Vice-President 1914-15, 1915-16.

Dr. Hoadley is at present serving in the capacity of Acting Secretary of the Franklin Institute, in the absence of the Secretary, Major R. B. Owens, who is in active military service overseas.

NEWS ITEMS.

SPECIAL ARTICLE.

President-Elect Dr. George A. Hoadley, 1918-1919.

Dr. George A. Hoadley was born in Sheffield, Mass., December 2, 1848, and graduated from Union College, Schenectady, N. Y., in 1874, with the degrees from both the Scientific and Civil Engineering Courses. Until 1888 Dr. Hoadley was principal of the High Schools in Argyle, N. Y., Fort Edward, N. Y., Florence and Northampton, Mass., after which he became head of the Department of Physics in Swarthmore College until 1894. From 1894 to 1914, he was Vice-President of Swarthmore College, when he retired from active college work.

"The Essentials of Physics," published

The Enemy Submarine.

Members of the Illuminating Engineering Society have received recently a pamphlet entitled "The Enemy Submarine." This pamphlet was issued to them as a result of the Society's affiliation with Engineering Council's War Committee of Technical Societies, which in turn is affiliated with the Naval Consulting Board. It is anticipated that other pamphlets on live war problems will be issued to members in the near future. It is hoped that the information thus conveyed will assist to promote good engineering consideration of these problems and stimulate members' inventive faculties to the end that aid may be rendered the Government in the effective prosecution of the war.

Protective Lighting.

There has been issued from the office of the Adjutant General of the War Department a pamphlet (document No. 800) on "Protective Lighting." This sets forth the general principles and practice of protective lighting of industrial plants and public works as a means of defense. It covers the lighting of building exteriors, the lighting of ship-building plants, lighting for construction work, lighting of piers, docks, bridges, dams and the protective lighting of interiors. It is illustrated to show practice and lighting equipment. The legend on the pamphlet states that it has been prepared for the U. S. Government by the Committee on War Service of the Illuminating Engineering Society. Copies may be obtained upon application to Major General J. McL. Carter, Chief Militia Bureau, Washington, D. C., or from the General Office where a limited number of copies are on hand.

Rehabilitation of Our Wounded.

The following is taken from a leaflet sent to the General Office by the Treasury Department, Bureau of Publicity, Washington, D. C.:

Perhaps none of the various uses to which the proceeds of the Liberty Loan are to be devoted appeals more strongly to the American people than the rehabilitation and re-education of our wounded men. To teach these men, to train and fit them for useful and gainful occupations, when by reason of loss of sight or limbs or other injuries they are rendered unable to pursue ordinary vocations, is the work in which every American has a heartfelt interest.

Compensation will be allowed them and family allowances will be paid their families as if they were in actual service while they are taking the training, and

every method known to science will be used to restore our wounded men to health and usefulness.

This work has been delegated by Congress to the Federal Board for Vocational Education. The board publishes at Washington a monthly bulletin, dealing with its work, called *The Vocational Summary*, which will be sent free to anyone upon request.

Opportunities with Bureau of Oil Conservation.

The Bureau of Oil Conservation, Oil Division, U. S. Fuel Administration, is desirous of securing a combustion engineer for each of the following districts, who will act as an inspector visiting all plants within his district using fuel oil and natural gas: Boston, Providence, New York City, Philadelphia, Pittsburgh, Buffalo, Detroit, Chicago, Minneapolis, Tulsa, New Orleans, and San Francisco.

It is desirable to have these men act as volunteers where possible, but the Administration is prepared to pay a reasonable compensation for men who cannot afford to give their services to the Government. Only men who have had experience in fuel oil and natural gas combustion would be of value.

Committee on Automobile Headlighting Specifications.

The specifications for acceptance testing of headlights under the New York State Law which were submitted to Secretary of State Hugo were adopted by him on June 25th after a public hearing at which a large number of manufacturers of headlighting appliances were present and discussed them. Only a few changes were made and these were entirely verbal. Copies of the

specifications may be obtained by applying to the Secretary of State, Albany, N. Y.

Night Lighting the Factory.

A series of articles entitled "Night Lighting the Factory" has been published in *The American Architect* of June 19-26 and July 10. Recognizing the importance of this subject, this journal published the articles for the purpose of furnishing architects sufficient data to approximate the amount of light required and the disposition of the lighting units. This understanding of the subject will make the architect more amenable to the requirements of the illuminating engineer and give them a better appreciation of the subject. The data is based on the requirements of the Pennsylvania Department of Labor and Industry and other sources of information.

The Illuminating Engineering Society aided in providing some of the material and illustrations. Mention is made of the work accomplished by the Society in developing the scientific aspects of this work and in aiding in the enactment of lighting laws in several states.

Life Insurance Company Urges Good Illumination.

One of the life insurances companies through its Policyholders' Health Bureau, has recently issued a bulletin to policyholders entitled "Eyesight and Illumination," urging the importance of good lighting as a means of avoiding accidents and promoting health. Some of the cuts appearing in this pamphlet were duplicates of those appearing in the Society's pamphlet, "Light: Its Use and Misuse."

The Publication of Synopsis and Abstracts of Papers.

The Committee on Papers is endeavoring this year to have included in the *TRANSACTIONS* either the full reprint or an abstract or a brief synopsis of every technical presentation made before a meeting of the Society. The need for keeping publication costs within a reduced wartime appropriation, as well as the desirability of directing the attention of members more particularly to those phases of illumination which have to do directly or indirectly with the prosecution of the war, has resulted in the decision to publish only abstracts or synopses of certain papers which in normal times would probably have been printed in full. Members desiring to obtain full manuscripts of any of the papers abstracted should write to the Society office, or to the author for the full manuscript, which in some cases it will be possible to loan.

In the August, 1918, issue of the *Proceedings* of the A. I. E. E. appeared the following Annual Report of the Lighting and Illumination Committee of that society. It is produced here inasmuch as we believe that it will be of interest to our membership by reason of its relation to illuminating engineering.

ANNUAL REPORT OF THE LIGHTING AND ILLUMINATION COMMITTEE.

To the Board of Directors:

I beg to submit on behalf of the Lighting and Illumination Committee the following report for the year 1917-18.

It is with regret that the Committee finds it necessary to report that again this year it did not seem feasible to hold a session of the Institute for the consideration of papers on illumination. The Committee held a meeting early in the year and proposed the following

subjects as suitable ones for presentation before the Institute:

(1) Intensive and Ornamental Street Lighting, as projected for a number of cities in the South and Southwest.

(2) A general discussion of Industrial Lighting Codes.

(3) A discussion of Standardized Methods of Lighting Cantonments, Aviation Fields, etc., provided the report of the I. E. S. Committee on this subject will be available for public presentation.

The Chairman was authorized to make an inquiry regarding the possibility of securing papers on one or more of these subjects and report the results subsequently to the Committee, but following a canvass of the situation it was found impossible to arrange such a program. Consequently, any thought of requesting one of the sessions of the Institute to discuss papers on illumination had to be abandoned. When conditions once again become normal, it will be possible to provide interesting programs on this aspect of electrical engineering, but for the time being it would seem that the Committee can do no more than remain intact and wait.

A brief summary of progress in electric illumination during the past year is appended.

Progress in Electric Illumination.

The general trend of practice for direct lighting is very decidedly toward units of low brightness. The extended use of the high-powered incandescent lamps has stimulated the appreciation of good diffusing devices which will give satisfactory light distribution but by their low brightness minimize glare. The enormous increase in commercial activities, particularly in those lines which are connected with supplies for the Government, has made night work the rule and brought a realization of the importance of proper illumination from the standpoint both of the maintenance of quality and quantity in production and of the health and comfort of the worker. Progress toward this end is evidenced in the revision of industrial lighting codes in several states

and by the appointment of a National Committee on Lighting to act as a subcommittee of the Advisory Commission-Council for National Defense for the preparation of suggested regulations to govern industrial lighting, which have subsequently been published in the form of a Code of Lighting by the Committee on Labor with a suggestion that the Code be put into effect in every state in the country.

War conditions have also brought about a more careful consideration of protective lighting and the best way to utilize it. Thus it has been found that in many cases inexpensive reflectors of the ordinary type may be used for lighting open spaces in and around a plant leaving the special flood lighting units for those locations requiring particular treatment. In many cases the use of a large number of properly shaded low-intensity units will avoid dangerous shadows better than high powered sources, even though the light flux from the latter is greater.

A sphere formerly considered impregnable held by the arc lamp has been finally invaded by the incandescent lamp. Motion picture projection work required light flux of extremely great intensity and the small area and high intrinsic brilliancy of the source of light in the arc has enabled it to meet the requirements in a way hard to duplicate. By using a mirror back of the filament and for a condensing lens one of the Fresnel type, it has been found possible to make an incandescent lamp which will give satisfactory results within a certain limited field of motion picture work.

The motion picture theatre has in itself become an arena in which unique lighting effects are being experimented with continuously. Thus in several cases, by the use of several circuits in each fixture, lamps of different colors may be lighted and thereby give a color tone to the whole illumination.

The action of the Government in attempting to save fuel by restricting its use for lighting purposes has shown in many localities the important part played by display lighting in maintaining the illumination of streets and sidewalks.

EDWARD P. HYDE,
Chairman.

Purely Personal.

Dr. A. E. Kennelly, acting head of the electrical engineering department of the Massachusetts Institute of Technology, has been awarded by the Franklin Institute its Howard N. Potts gold medal for his invention of the hot-wire anemometer and his application of this device to the measurement of convection from small heated wires. Dr. Kennelly is Chairman of our Committee on Nomenclature and Standards.

Dr. A. S. McAllister, past-President of our Society, has gone to Washington, D. C., as assistant to Major Thompson in the Progress Section of the Control Bureau of the Ordnance Department. Prior to going to Washington Dr. McAllister had been active in New York in engineering society committee work relative to war matters.

M. C. Turpin, formerly assistant to manager, Westinghouse Department of Publicity, has resigned to enter the Federal service as assistant to manager, Technical Publicity Bureau, Ordnance Department, Washington, D. C. Mr. Turpin's work will be on the dissemination of information from the War Department to manufacturers, through the medium of the trade press. Mr. Turpin is a graduate of Alabama Polytechnic Institute and of Cornell University. After several years' experience in the construction and operation of central station plants, he entered the Westinghouse Department of Publicity in 1909.

Dr. Morton G. Lloyd, Electrical Engineer in charge of safety work in the Bureau of Standards, Washington, D. C., has been appointed a member of the Electrical Committee of the National Fire Protection Association, to represent the Bureau.

Dr. Lloyd was for many years a member of the scientific staff of the Bureau during the period of its early development. From 1910 to 1917 he was Technical Editor of the *Electrical Review and Western Electrician*. In 1917 he returned to the Bureau and upon the resignation of Mr. W. J. Canada was put in charge of electrical safety engineering.

Dr. Lloyd is a fellow of the American Institute of Electrical Engineers and has served upon its Standard Committee and various other committees. He is Vice-President of the Illuminating Engineering Society and a member of its Committee on Lighting Legislation. He is a member of the Divisional Committee on Lighting of the Advisory Commission of the Council of National Defense, a member of the American Association for Labor Legislation and of numerous scientific and technical societies.

I. E. S. WAR NOTES.

Honor Roll.

The following members have become affiliated with the active military or naval service of the United States. Previous numbers of the TRANSACTIONS give the names of other members who have previously enlisted.

Leigh H. Bair
 Guy S. Brandreth
 S. B. Burrows
 Paul C. Egan
 Wm. W. Edie
 Harold Goodwin, Jr.
 Harry J. Gross
 Milton B. Hastings
 Wallace P. Hurley
 J. B. Juvenal
 Dugald C. Jackson
 Edw. F. McNally
 Josephus E. Hamilton Stevenot

GENERAL OFFICE.

Co-operation with Section Boards.

At about this time each year, the newly elected Boards of Managers for the several Sections meet to organize and prepare plans for the activities of their respective Sections during the coming fiscal period.

Each Section Secretary has in his possession a file containing names and addresses of the members in his Section, correspondence files, outlines of business procedure, bound reports of the reports of Section meetings and minutes of the meetings of the Board of Managers of the Section.

In order to assist the Section boards in the conduct of their work, the Guide for Section Procedure gives in some detail the custom and business routine to be followed by the Section. The General Office, however, invites from the outgoing boards, suggestions and criticisms to be incorporated in Guide for Section Procedure, which they believe might be helpful to the newly elected Section boards.

OBITUARY.

On July 1, 1918, Francesco Laurent Godinez, consulting engineer, died at his home in Jersey City, N. J., at the age of 38.

Mr. Godinez was an associate member of the Society from February, 1909, to June, 1915. He was connected with the H. L. Doherty Company and the Holographane Glass Company of New York, and subsequently associated himself with

Mr. A. Jackson Marshall, consulting engineer, for one and one-half years.

Lieutenant Colonel Liebmann is Killed in Action.

Leading his men in action with the British somewhere in France, Lieut. Colonel Morris N. Liebmann, second in command of the 105th Infantry, was killed by a rifle bullet. The date of death was August 8th.

Colonel Liebmann was a veteran of the New York National Guard, having served nearly eighteen years. Graduated at the University of Nebraska, he served throughout the Spanish-American war with a guard regiment from Nebraska. His first service in the New York State organization placed him as a private in Company I, 23rd Regiment of Brooklyn. He won advancement through the various ranks and was Regimental Adjutant with the rank of Captain when the 23rd went to Pharr, Texas, for the border service, in 1916. A year ago last April he was promoted to a Lieutenant Colonel.

A year ago this month Colonel Liebmann went to Spartanburg, S. C., where he was transferred to succeed Lieut. Col. Hutchinson as second ranking officer of the 105th Infantry, crack organization of the 27th Division, U. S. A.

Colonel Liebmann was Vice-President of the Foote-Pierson Company, 160 Duane Street, manufacturers of electrical apparatus, and was an associate member of the Society since 1913. His death has been the first reported among our members who are serving at the front with the forces of the Allies.

ILLUMINATION INDEX.

Prepared by the Committee on Progress.

An index of references to books, papers, editorials, news and abstracts on illuminating engineering and allied subjects. This index is arranged alphabetically according to the names of the reference publications. The references are then given in order of the date of publication. Important references not appearing herein should be called to the attention of the Illuminating Engineering Society, 29 W. 39th St., New York, N. Y.

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TRANSACTIONS

OF THE

Illuminating Engineering Society

PART I -- SOCIETY AFFAIRS

VOL. XIII

OCTOBER 10, 1918

No. 7

COUNCIL NOTES.

ITEMS OF INTEREST TAKEN FROM
THE COUNCIL EXECUTIVE COM-
MITTEE MEETINGS OF AUGUST
14 AND SEPTEMBER 12, 1918.

New Members.

Upon recommendation of the Board of Examiners, the following applicant was elected to membership on August 14, 1918:

One Associate Member.

T. A. HUNTER
Lighting Specialist—Sales,
Southeast General Electric Co.,
R506 Interurban Bldg.,
Dallas, Tex.

At the meeting of the Council Executive Committee on September 12th, the following applicants were elected to membership upon recommendation of the Board of Examiners:

Two Members.

JOSEPH J. McLAUGHLIN
Illuminating Engineer,
Westinghouse Lamp Co.,
Bloomfield, N. J.

WILLIAM T. RASCH
Assistant and Acting Engineer of
Utilization,
Consolidated Gas Co.,
128 E. 15th St.,
New York, N. Y.

Two Associate Members.

CHARLES SEYMOUR
P. O. Box 5114,
Johannesburg, Transvaal,
South Africa.

ALBERT HENRY YOUTHED
Electrical and Mechanical Engineer,
281 St. Andries St.,
Pretoria, Transvaal,
South Africa.

Popular Lecture on "Protective Lighting."

The popular lecture on "Protective Lighting" approved by the Committee on Papers, received final approval for presentation by the Council Executive Committee on September 12th.

It is the third of a series of popular lectures prepared under the auspices of the Committee on Popular Lectures of the Illuminating Engineering Society and on page 384 of this issue a synopsis of the lecture will be found. The treatment of the subject is popular throughout.

The lecture is illustrated by thirty-four lantern slides and can be presented in an hour's time.

It may be reserved for presentation, upon application to the General Offices of the Society.

Discontinuance of Exchange Copies of the Transactions.

In view of impending governmental orders requiring that the distribution of exchange copies of publications be discontinued as much as possible, a temporary committee was appointed on August 14th, to consider ways and means of complying with this request. At the meeting of the Council Executive Committee held on September 12th the committee reported that it was their opinion that the number of copies printed for each issue could and should be curtailed in view of the government's request that exchange copies be eliminated. At the same time, the number usually held in stock to fill back numbers will be reduced. The Society will be glad to furnish back numbers from the present stock, but as a war measure cannot order or carry in stock any quantity, anticipating future orders.

SECTION ACTIVITIES.

NEW YORK.

Meeting of Board of Managers.

The 1918-1919 Board of Managers have had thus far two well attended and enthusiastic meetings.

At the meetings in July and September various committees were appointed, among them, Attendance-Publicity, Dinner and Reception, Papers, Exhibition, Membership, and the Board of Examiners.

The regular monthly meetings of the New York Section are to be held on the second Thursday of each month at 8.00 p. m. in the Engineering Societies Building.

The New York Section Board of Managers will meet regularly on the last Thursday of each month at 4.00 p. m.

The October meeting of the New York

Section has been abandoned. Inasmuch as the 1918 Convention is to be held in New York during that month, it was decided that the New York Section lend its activity and co-operation toward making the Twelfth Annual Convention of the Society a successful one.

News has reached the General Office that a number of committees have already been appointed and that activities have commenced. No doubt is felt that the high standards of work accomplished heretofore by the New York Section Committees will be maintained during the coming season. Below is printed a list of the committees appointed thus far:

Exhibition Committee:

A. R. Dennington, Chairman
E. H. Peck

Membership Committee:

O. H. Caldwell, Chairman
Norman Macbeth
C. B. Le Page
A. T. Baldwin
E. B. Stott
W. J. Clark
G. L. Diggles
R. B. Burton
Walter Neumuller

Papers Committee:

L. J. Lewinson, Chairman
W. T. Dempsey
M. W. Hanks
G. E. Hulse
A. R. Dennington
W. T. Rasch
W. H. Rolinson
G. W. Magalhaes

Attendance and Publicity Committee:

R. B. Ely, Chairman
E. H. Hobbie
W. E. Brewster
L. H. Graves

Dinner and Reception Committee:

W. J. Clark, Chairman
 Z. N. Hyer
 R. H. Maurer
 Clarence L. Law
 J. P. Radcliffe, Jr.
 S. W. Van Rensselaer

NEWS ITEMS.

Honor Roll.

The following members have become affiliated with the active military or naval service of the United States or its Allies. Earlier numbers of the TRANSACTIONS give the names of other members who have previously notified the General Office of their enlistment.

R. W. Ashley
 Peter Junkersfeld
 Alten S. Miller
 Alfred W. Heitman
 L. C. Howland
 George B. Nichols
 W. J. Huddle
 H. Syril Dusenbury

At the meeting of the National Association of Stationery Engineers held in Cincinnati, Ohio, September 10, 1918, President G. H. Stickney delivered a short talk on the lighting of offices and stores.

New York State Industrial Lighting Code.

The New York Industrial Commission under the jurisdiction of the Department of Labor has just published the Rule relating to the lighting of factories and mercantile establishments in New York State. This Rule became effective July 1, 1918.

The Rule consists of six sections which follow closely the sub-divisions

of the I. E. S. factory lighting code, the chief differences being as follows: The New York State Code specifies a minimum of 1.00 foot-candle (instead of 1.25 foot-candles) for rough manufacturing operations and includes an additional classification of 0.50 foot-candle between the values of 0.25 foot-candle and 1.25 foot-candles given in the I. E. S. Code. The New York State Code requires all lamps located less than 20 feet above the floor level to be suitably shaded, except where such lamps are used for a temporary decorative purpose. For emergency lighting the New York State Code specifies a minimum of 0.25 foot-candle.

In an Appendix to the Code, the principles of good lighting, both natural and artificial, are briefly discussed and it is pointed out that the intensity values specified in the Rule give the lowest illumination with which the employee can be properly safeguarded against both accident and eye-strain, and that it is to the advantage of the employer to provide the higher values which are listed in an accompanying table of "Desirable Illumination," as such provision results in reduced eye-strain, greater accuracy of workmanship, increased production and less spoilage.

The Appendix also contains a table of minimum intensities proposed for several hundred industrial operations and processes. It is stated that this classification is tentative and is submitted for the guidance of factory owners and managers, and that it is the intention of the Industrial Commission to make the intensity requirements of this table mandatory on July 1, 1919, if after public hearings and a year's experience the same are found to be adequate and just.

In the preparation of this Code the New York State Industrial Commission

received the co-operation of the I. E. S. Committee on Lighting Legislation.

Copies of the Code (Bulletin No. 18) may be obtained by addressing the Bureau of Industrial Code, 230 Fifth Ave., New York City.

Wartime Lighting Economies.

Included in the program of the annual convention held on October 10th is the presentation of "Wartime Lighting Economies," a treatise which has been prepared by our Committee on War Service and submitted to the United States Fuel Administration to serve as the basis of the Fuel Administration's propaganda for economy in lighting on the part of the public at large. It is hoped that the discussion of this non-technical, popular treatise will elicit additional ideas which will be of utility to the Fuel Administration. The treatise with its discussion on the floor of the convention will strike a timely note expressive of the desire of our membership to be helpful in the national emergency.

A limited number of advance copies are at the General Office and can be obtained upon application to the Society headquarters, 29 W. 39th St., New York, N. Y.

Scientific Industrial Illumination.

In a booklet entitled "Scientific Industrial Illumination" recently published by the Holophane Glass Company, illustrations are reproduced from the I. E. S. pamphlet, "Light: Its Use and Misuse."

Particular attention is called to adequate illumination. "Scientific Industrial Illumination" recommends that correct illumination intensity be used for various classes of work and refers to the illumination intensities advocated by the Illuminating Engineering Society and adopted as laws by the states of

New Jersey, Pennsylvania and Wisconsin.

The question of glare, spoilage and accidents resulting from poor illumination are also covered in this booklet.

Purely Personal.

Word has reached the General Office that ARTHUR J. ROWLAND, former Dean of The Drexel Institute, Philadelphia, Pa., is affiliated with the Federal Board for Vocational Education in Washington, D. C., in the division for rehabilitation of disabled soldiers and sailors. Here, as Mr. Rowland expresses it, he "believes he can do a good work and be of real service." Mr. Rowland's present address is in care of the Federal Board for Vocational Education, N. W. Cor. 6th and G Sts., Washington, D. C.

FREDERIC A. DELAY, Secretary of the Chicago Section for 1917-1918, formerly Head Instructor of the Chicago Central Station Institute, has recently moved to Milwaukee where he has accepted a position as Superintendent of Electrical Departments of the Mechanical Appliance Company, manufacturers of Watson D. C. and A. C. Motors.

Membership in Foreign Countries.

Of late a number of applications for membership have been received from very distant countries. It is pleasing to note that the Illuminating Engineering Society is represented by members in South Africa, South China, Netherlands, China and Japan. The gospel of good illumination as advocated by the Illuminating Engineering Society no doubt has penetrated these distant lands.

It is extremely noteworthy that notwithstanding the World War raging on the soil of France those of our members living in France and England have found it of sufficient importance, even

in these times of sacrifice, to retain their membership in the Illuminating Engineering Society.

The I. E. S. in War Service.

Thus far statistics at the General Office indicate that of the total individual membership of the Illuminating Engineering Society 7 per cent. are in war service. In addition to these, there are many others who have offered their services and are with various departments at Washington. The Chicago Section has given nineteen of its local members, the New England Section four, the New York Section twenty-eight, the Philadelphia Section twenty-one, Pittsburgh Section eight, and ten of our members not affiliated with any section are also in war service. A good number of these have seen active war-

fare since the early days of America's entry into the World War.

In accordance with a ruling of the Council those of our members in war service who desire it, are carried free on the rolls of the Society during their period of affiliation with the forces of the Allies. The TRANSACTIONS are suspended in this interim.

The General Office has thus far been apprised of the fact that two of our members, Lieut. Colonel M. N. Liebmann and Flying Cadet J. F. Dick, both of the New York Section, have made the supreme sacrifice.

The Society aims to assist its war service members in every way possible, no matter whether they are in domestic or foreign service and would appreciate receiving from them personal items of their work or experience which would be of interest to the membership.

ILLUMINATION INDEX.*Prepared by the Committee on Progress.*

An index of references to books, papers, editorials, news and abstracts on illuminating engineering and allied subjects. This index is arranged alphabetically according to the names of the reference publications. The references are then given in order of the date of publication. Important references not appearing herein should be called to the attention of the Illuminating Engineering Society, 29 W. 39th St., New York, N. Y.

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TRANSACTIONS

OF THE

Illuminating Engineering Society

PART I -- SOCIETY AFFAIRS

VOL. XIII

NOVEMBER 20, 1918

No. 8

COUNCIL NOTES OF INTEREST.

COUNCIL MEETING OF OCTOBER 9, 1918.

The annual joint meeting of the old and new Councils was held on Wednesday, October 9th.

President Stickney conducted the first part of the meeting, winding up the affairs of the 1917-1918 administration. Reports and statements from Sections and Committees were presented; the General Secretary's report was read; a summary of the finances of the Society was presented and with the passing of these, President Stickney introduced his successor, George A. Hoadley as President.

After a short introductory address in which President Hoadley earnestly requested the co-operation of the members of the Council to help make his administration as successful as the one just passing, the first meeting of the 1918-1919 Council was called to order; interrupted only by the sincere congratulations extended to retiring President Stickney for the many splendid accomplishments achieved by his committee and aides during his term of office.

Time and Place of the Council Meetings for 1918-1919.

The Council will meet regularly during the fiscal year 1918-1919 at the General Office, on the second Thursday of each month at 2.00 p.m. During the months of July, August and September, however, there are no regular Council meetings scheduled, inasmuch as the Council Executive Committee meets to transact affairs of the Society during these three months.

Reports of Committees to the Council for 1917-1918.

Following the usual custom, reports were read of the activities of the various committees for the 1917-18 administration.

A vote of thanks was extended to the retiring chairmen of committees and sections for their co-operation and earnest devotion.

Copies of the reports submitted will be printed in the TRANSACTIONS in the near future.

New Members.

Upon recommendation of the Board of Examiners the following applicants were elected to membership:

One Member.

JOHN A. ORANGE
Research Chemist,
General Electric Co.,
Schenectady, N. Y.

Four Associate Members.

JOHN Q. ADAMS

Architect and State Building Inspector,

Ohio State Industrial Commission,
204 Majestic Theatre Bldg.,
Columbus, Ohio.

H. W. HAHN

31 W. 46th St.,
New York, N. Y.

ELLIOT REID

Assistant to General Manager,
Westinghouse Lamp Co.,
165 Broadway,
New York, N. Y.

R. E. WHITCOMB

1581 Broadway,
New York, N. Y.

Other Changes in Membership.

The death of J. J. Knight, of Kalamazoo, Mich., was reported to the Council.

Three members and thirteen associate members have requested to be resigned, and their names were presented to the Council:

Members.

(Subject to Informal Reinstatement upon payment of back dues.)

F. CARPENTER
CARL HERING
A. B. MACBETH

Associate Members.

(Subject to Informal Reinstatement upon payment of back dues.)

T. G. ALLAN
N. H. BOYNTON
W. L. BUZBY
H. L. DALLAHAN
C. W. FRENCH
W. G. HOUSEKEEPER
C. A. LEARNED
R. L. LLOYD
SINCLAIR MAINLAND
A. P. LITTLE

N. A. THOMAS

E. C. UHLIG

W. H. WOHNUS

Annual Report of the General Secretary for 1917-1918.

As is the usual custom the annual report of the General Secretary was read.

It embodies abstract of the achievements of the various committees of the Society during the year, summary of the finances of the Society, and chiefly among other things the assistance rendered by the Committee on War Service to the various Governmental departments.

Engraved Honor Roll.

A hand engraved Honor Roll of the members of the Society in War Service will very soon decorate a wall of the Council Room. President Hoadley authorized the following committee to make arrangements for the preparation of an honor roll and appointed H. A. Hornor, chairman of the committee. Those associated with him are Messrs. Johnson, Hoyt, Stephens, Law and Hertz.

Fourth Liberty Loan.

As a result of the decision of the Council \$500 was invested in the purchase of a Liberty Bond of the Fourth Loan. This purchase was made by the Treasurer through the Electrical Industries Committee, New York City.

Appointments.

On page III of this issue will be found the committees appointed by President Hoadley at this meeting.

As President Hoadley expresses it, "he hopes to be able to get all his committees appointed and working in a very short time."

Council Executive Committee Meeting.

A meeting was called on October 24th, at which time the following resolution was prepared on the death of Robert French Pierce, a Director of the Society.

Resolved, That the Executive Committee of the Society having just learned with deep regret of the death of our friend and associate, R. French Pierce, desires to place on record our appreciation of the ability and devotion which he has always shown and served in the interest of the Society. During the period of his connections with the Society he served as an active member on various committees and was a Director of the Society at the time of his death. We deeply deplore the loss and offer our profound sympathy and sincere condolence to his family. He gained the admiration and esteem of all who were associated with him, and his memory will remain dear to us all;

Resolved, That this tribute be placed on the minutes of the Society, and that the General Secretary be instructed to convey it to his family.

The General Secretary forwarded a copy of the resolution to the family of the deceased, and the resolution was ordered incorporated in the minutes of the Society.

Representation of the I. E. S. on the Advisory Committee, Engineering Division of the National Research Council.

It is pleasing to note that the National Research Council extended an invitation to the Society to be represented on the Advisory Committee, Engineering Division of the National Research Council of the General Staff, United States Army. The invitation was read at the meeting and President Hoadley requested Edw. P. Hyde to serve as the representative of the I. E. S. Dr. Hyde has accepted the appointment.

1918 Convention.

The 1918 Convention was held in the

Engineering Societies' Building, New York City, Thursday, October 10th.

Though confined to one day, it was no less important or significant than its predecessors, and held the sustained attention of all.

It was, in every sense, a working Convention for the War, and every minute was devoted to matters of especial importance under war conditions. Requirements of secrecy prevented the discussion of the most vital applications of lighting in warfare. Attention was rather directed to those problems where publicity was desirable as a means of securing wide co-operation in carrying out economies and improvements in lighting practice.

The usual addresses of welcome and other formalities were dispensed with. The morning session was devoted to important reports of committees and the address of the President. The report of Council given by the General Secretary indicated the satisfactory condition of the Society, financially and otherwise, and also indicated the extent to which efforts had been directed toward meeting the country's need.

In connection with the report of the Committee on Automobile Headlighting Specifications, the Hon. Francis M. Hugo, Secretary of State, for the State of New York, addressed the Convention with regard to the regulations recently adopted in that commonwealth.

Dr. E. P. Hyde, President of the U. S. National Committee on Illumination, made a statement regarding the war status of that committee and the International Commission.

Mr. L. B. Marks in addition to reporting for the Committee on Lighting Legislation, spoke for the Divisional Lighting Committee (Council of National Defense) in regard to the Industrial Lighting Codes.

Captain Scott, Secretary of the War Committee of Technical Societies, spoke of the work of the committee and the methods of handling inventions to insure prompt application of important discoveries. The session was closed by a short but inspiring Liberty Loan talk by T. C. Martin.

In the afternoon, Wartime Lighting Economies, a report made by the Committee on War Service to the Fuel Administration, brought out the necessity for economy and suggested many important methods of eliminating lighting wastes.

Four papers developed the importance of maintaining good practice in industrial and protective lighting and contributed valuable suggestions to that end.

The large amount of material coming before the Convention restricted the discussion somewhat, especially in the morning session, but this unavoidable condition will be rectified, as announced by the Chairman, through an attempt to secure full discussion in the TRANSACTIONS.

The War Dinner in the evening at the McAlpin, presided over by D. McFarlan Moore, was well attended. As expressed by the retiring President, it was not arranged as an entertainment, but rather to enlist the hearts of the membership in the National Service, as the day sessions had enlisted their intelligence. After a few words by Past-President Stickney and the incoming President Dr. Hoadley, Mr. O. Monnett, representing the Fuel Administration, and Dr. R. A. Millikan of the National Research Council, gave most excellent addresses bearing messages from their respective organizations.

Mr. W. L. Parker kindly favored the guests with several excellent and timely

solos, for which Mrs. Parker played the accompaniment.

The dinner and Convention was closed with the presentation of U. S. Government films for the instruction of soldiers. These were made available through the courtesy of the General Staff of the War Department.

It was generally agreed that the Convention was not only a most successful affair, but one of great value to the country and to the lighting art. The proceedings, as reported in the TRANSACTIONS, will be of considerable interest to the membership and to all others interested in lighting, especially with regard to wartime problems.

SECTION ACTIVITIES.

NEW YORK.

At the meeting of the Board of Managers, held on Thursday, October 31st, R. E. Harrington was appointed Secretary of the New York Section to succeed L. C. Porter, resigned. Mr. Porter has enlisted in the United States Navy, and while his resignation was received with regret the character of his new work and his service to the Government has ameliorated this feeling.

The first meeting of the Section is scheduled for November 14th at which time the 1917-1918 Report of the Committee on Automobile Headlighting Specifications will be presented for discussion. Details concerning this meeting will be printed in the forthcoming issue of the TRANSACTIONS.

PHILADELPHIA.

At the time of this issue going to press, word has reached the General Office that Ward Harrison will present a paper at the first meeting of the Section on November 15th, on "Accessories

for Industrial and Protective Lighting." On account of the epidemic of influenza public meetings were prohibited in Philadelphia at the time that this Section was to meet in October, and for this reason the first meeting will be held on November 15th.

NEW ENGLAND.

On October 18th, the Board of Managers of the New England Section held their meeting in Boston, Mass.

Plans have been formulated to hold the first Section meeting on Friday, November 15th, at which time A. L. Powell will speak on the subject "Cotton Mill Lighting." The subject and the speaker bid well to a large attendance and an enjoyable evening.

The Chairman of the Membership Committee of the New England Section for 1918-19 will be R. A. Fancy. H. F. Wallace has been appointed Chairman of the Papers Committee and F. A. Gallagher, Jr., Chairman of the Publicity Committee.

Keen interest is manifested in the new management of the New England Section and indications point to a successful season.

CHICAGO.

Owing to Chicago ordinance prohibiting public meetings of any kind during the epidemic of influenza, the meeting scheduled for October 28th was cancelled. Professor C. E. Clewell was to have addressed the Chicago Section on the subject "Industrial Lighting as a War Problem."

NEWS ITEMS.

Looking through the Rotogravure Section of a Sunday edition of the *New York Times*, we discovered a photograph of our Past President, Van Rens-

selaer Lansingh. Negotiations were made with the *New York Times* and we reprint here, through their courtesy, the photograph taken in Paris of Mr. Lansingh and his associates who were instrumental in the founding of the Technology Club of Paris.

We learned that Van Rensselaer Lansingh was a member of the Engineering Committee of the Council of National Defense in Washington, D. C., during the Spring of 1917. He was asked by the authorities of the Massachusetts Institute of Technology to go to Paris to look after the interests of Technology men in service abroad. Before sailing, however, a meeting was held with representatives from Yale, Harvard, Princeton and Columbia Universities looking to joint action for all American colleges and universities. Prof. Nettleton of Yale who was the prime mover in this undertaking proceeded to organize the colleges in this country, while Mr. Lansingh sailed for Europe in June to study the conditions there. While waiting for the situation to crystallize in America, he started the Technology Club of Paris, which for the next three months became the center of activities for American college men. This was later merged with the American University Union in Europe, which was duly formed in America with about thirty leading colleges. Since then the Union operates a large hotel in Paris for the benefit of all American college men and also has headquarters in both London and Rome. Its work consists of two different activities: First, in looking after the welfare of college men abroad; and second, in cementing closer relationship between the American, French, English and Italian Universities. The work in the latter respect has been fully as successful as the former.

Mr. Lansingh served as Assistant Director and Business Manager of the Union from the time of its organization until his return to America in July, 1918.

Through the Society's representatives upon Engineering Council's War Committee of Technical Societies, the following brief abstracts of problems on which assistance is desired by the Inventions Section of the General Staff are placed before the membership. Members who deem it likely that they might offer some suggestion which will be of use in this connection are invited to apply to the General Office for a more detailed statement of any one or more of these problems which the War Committee of Technical Societies has prepared.

THE FOLLOWING IS A LIST OF THE PROBLEMS:

- Problem 1: *Liaison Problem*, of finding a new means of communication whereby closer liaison may be obtained between the different elements of front line and rear troops.
- Problem 2: *An Aviation Problem*, an arrangement for mounting a compass on an aeroplane to be away from magnetic influence of engine and still easily read by operator. This is required for night flying work.
- Problem 3: *A Better Fire Control Gear for Fixed Machine Guns on Aeroplanes*.
- Problem 4: *Specifications for New Rear Sight Desired for the United States Rifle, Calibre 30, Model of 1917*. With the present rear sight the rifleman cannot readily bring the point of impact of the shots to coincide with the point of aim.
- Problem 5: *Pyrotechnic Smoke Signals*. A suitable chemical substitute for Red Saxony Arsenic now used in the manufacture of yellow smoke signals. A suitable formula for a red smoke signal is also desired.
- Problem 6: *Hand Grenade*. An improved hand grenade is wanted. The specifications for rifle grenade and ideal impact grenade will be furnished on request.
- Problem 7: *Improvement in Cable Braces for Aeroplanes*. The method of attaching ends of cables by bending the end over a protecting liner and wrapping the overlapping end with brass wire which is afterwards soldered, is unsatisfactory, wasteful and expensive. A very simple method of anchoring cable ends would greatly speed up the production of aircraft.

A letter from C. L. McIntyre, Ensign, U. S. N. R. F., Assistant Mobilization Inspector, Eastern Division, was received at the General Office and is printed herewith. Ensign McIntyre also requested that wide publicity be given to his letter, and urges men who feel qualified to make application immediately.

Herewith is a copy of the letter received:

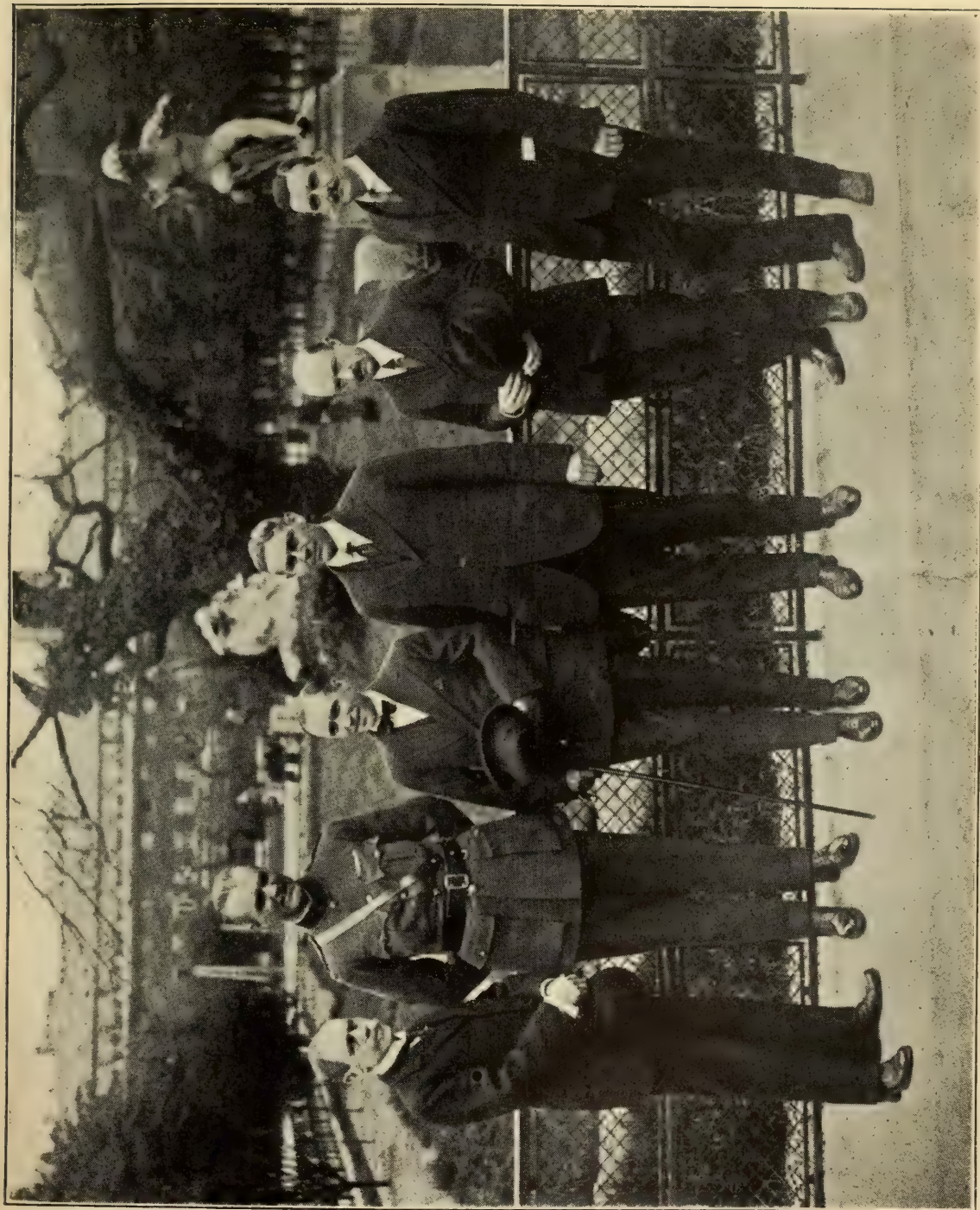
The urgent need of the Navy for men to be trained as Engineering Officers has prompted me to write you and your members to ascertain if any are interested in joining this branch of the Service.

The knowledge necessary to qualify for the course given at the U. S. Navy Steam Engineering School is that a man be either a graduate or one who has pursued a Mechanical, Electrical or Civil Engineering Course in some recognized University. Men who have had a practical experience equivalent to the above courses have made excellent material also.

The work of the School has been embodied in a course of training covering five months, viz.:

One month training at the Naval Training Camp, Pelham, N. Y.

One month of technical work at the U. S. Navy Steam Engineering School, Hoboken, N. J.



The third gentleman from the left is Van Rensselaer Lausings, Past President of the Illuminating Engineering Society.

Two months practical training on board ships and in shops in the vicinity of New York.

One month finishing course of instruction at U. S. Navy Steam Engineering School, Hoboken, N. J.

If men are found eligible by the Navy Mobilization Inspector, they will be individually inducted through their local boards as Apprentice Seaman and upon qualifying for the School will be rated Chief Machinist Mate with pay of \$83.00 and, in addition subsistence and lodging. If they finish the course successfully they will be given the rank of Ensign.

Applications should be sent to me at the address given below.

Very truly yours,

C. L. MCINTYRE,
Ensign, U. S. N. R. F.,
Assistant Mobilization Inspector,
Eastern Division,
225 W. 42nd St.,
New York, N. Y.

Under the auspices of the Divisional Committee on Lighting, Dr. Louis Bell, acting for J. W. Cowles, representative of the State of Massachusetts, arranged through the courtesy of the Edison Electric Illuminating Company of Boston, for a meeting of factory inspectors of the State of Massachusetts. The meeting was held on Thursday, October 31st.

This session was for the special guidance of the factory inspectors of the Board of Labor and Industries in improving the conditions of industrial lighting throughout the State. It consisted of a series of somewhat informal talks by various specialists in lighting, together with laboratory demonstrations of practical lighting, its technique and measurement. The program was as follows:

1. The General Principles of Artificial Lighting. By Dr. Louis Bell, Consulting Engineer of the Edison Electric Illuminating Company, Past President of the Illuminating Engineering Society.

2. The Hygienic Aspect of Lighting. By Dr. F. H. Verhoeff, Pathologist and Ophthalmic Surgeon, Massachusetts Eye and Ear Infirmary; Asst. Prof. of Ophthalmic Research, Harvard University.

3. How Illumination is Measured. By S. L. Keyes, Photometrist of Edison Electric Illuminating Company.

Recess.

4. Demonstrations of Lighting Intensities with Relation to Work.

5. The Lighting of Textile Mills. By Prof. William L. Puffer, Consulting Engineer.

6. Machine Shop Lighting. By Mr. S. C. Rogers, General Electric Company.

7. General Industrial Lighting. By Mr. H. W. Jordan, Illuminating Engineer of the Edison Electric Illuminating Company.

It is believed that this instructional session will prove of real service in indicating to the inspectors the directions in which attention should be pointed in investigating industrial conditions, and it is hoped to follow this up by other conferences with a view to putting into effect a definite code which can be and will be enforced.

MR. ARTHUR J. SWEET of Milwaukee, as a delegate of the Illuminating Engineering Society, addressed the American Association of Railway Surgeons on the afternoon of October 17th at the Hotel Sherman, Chicago. His subject was "Wise and Unwise Wartime Economies in Lighting."

Reprints of the full paper entitled "Light, Fine Art the Sixth" by Mrs. Mary Hallock-Greenewalt, abstract of which appeared in the last issue, may be had upon application to Mrs. Hallock-Greenewalt at 1424 Master Street, Philadelphia.

I. E. S. WAR NOTES.

A Message from President

George A. Hoadley.

To the Members of the Illuminating Engineering Society:

There is probably no one connected with the Illuminating Engineering Society who does not know that the services of its many members are at the command of the Government to be used for winning the war.

Those who were fortunate enough to be present at the one-day Convention held on October 10, 1918, came away with their enthusiasm more fully aroused and their determination to do their share more firmly fixed.

That this would be the natural result of the work of that convention was foreseen at the Council meeting on October 9th, and was a deciding factor in the decision that was adopted regarding the Committee on War Service.

This decision was that the work of this committee is of so great importance that its members should consist of the entire membership of the Society, that there should be a small executive committee consisting of Preston S. Millar, Chairman, C. W. Cutler, S. E. Doane, W. A. Durgin, Edw. P. Hyde, Clarence L. Law, L. B. Marks, J. F. Meyer, Wm. J. Serrill and G. H. Stickney, and that of this number Dr. Hyde be appointed as a member of the Advisory Committee of the Engineering Division of the National Research Council, representing the Illuminating Engineering Society on that committee.

The general plan of operation will be that all activities that would normally come before our Committee on War Service will be considered by the executive members of that committee who will select from the general membership of the Society those who in their opinion

are best qualified to take up the work that needs to be done. This practically means that every member shall consider himself a minute man subject to call at any time.

The fact that one member of our Executive Committee on War Service is a member of the Advisory Committee of the Engineering Division of the National Research Council will serve to co-ordinate the work of the Illuminating Engineering Society with that of the National Research Council, by providing a direct channel through which there can be submitted for the consideration of our Executive Committee on War Service any problems that come within its province.

The six billion loan has been raised; the war is won and there will come a call, possibly greater than any the war has yet brought, for help in the problems of national and international readjustments.

Honor Roll.

Information has reached the General Office that the following members have become affiliated with the active military or naval forces of the United States. Earlier issues of the TRANSACTIONS give the names of members who have previously enlisted:

S. G. Swisher
John Millis
W. G. Eager
H. Syril Dusenbury
Edw. G. Pratt

In sending announcements of their affiliation with certain branches of the military or naval service, all members are requested to give their rank, division with which they are connected, their present service address and their home address.

GENERAL OFFICE.

We are anxious to learn the whereabouts of a few of our members, who have evidently moved from their former addresses, and have not advised the General Office of such changes. Below are the names of these members of the Society and their former addresses.

Information leading to their present locations may be forwarded directly to the General Office of the Society.

E. CANTELO WHITE

Duplex Lighting System, Inc.,
122 S. Michigan Ave.,
Chicago, Ill.

R. E. BITNER

1342 Girard St.,
Washington, D. C.

EMERY ROTH

343 High St.,
Newark, N. Y.

J. T. ROFFY

Fine Science Laboratories,
Roffy-Baker Co.,
203 Highland Bldg.,
Pittsburgh, Pa.

W. A. DARRAH

Assistant Chief Engineer,
Ohio Brass Co.,
Mansfield, Ohio.

Members desiring to present written discussions for convention papers or reports, which have not already appeared in this number, are requested to do so immediately. Such discussions should be addressed to the Chairman of the Committee on Papers, Mr. G. H. Stickney, Fifth and Sussex Streets, Harrison, N. J.

OBITUARY.

The recent epidemic of influenza which swept the country claimed in its toll a Director of the Society, a man who was considered an authority on the subject of illumination and whose papers on this subject have been presented before several technical societies. Robert French Pierce passed away on October 19th, a victim of pneumonia, after a very brief illness at his home in Media, Pa. His widow and three children survive him.

Mr. Pierce was born in Salem, Iowa, in 1879. He was a graduate of Harvard University and a member of the Harvard Club in New York. Since July, 1911, Mr. Pierce was associated with the Welsbach Company, in the capacity of chief illuminating engineer. He was a Director of the Society from October 1, 1917, up to the time of his death.

Great sorrow was expressed at the news of the death of Mr. Pierce, and at the Council Executive Committee meeting held on October 24th resolutions regarding his death were adopted, a copy of which were sent to the family of the deceased. The resolutions are printed in another column of this issue.

Funeral services were held in Philadelphia on October 22nd, and in accordance with the expressed wish of Mr. Pierce his body was cremated.

Word has just reached the General Office that Dr. Charles H. Williams of Boston died on June 8, 1918.

ILLUMINATION INDEX.*Prepared by the Committee on Progress.*

An index of references to books, papers, editorials, news and abstracts on illuminating engineering and allied subjects. This index is arranged alphabetically according to the names of the reference publications. The references are then given in order of the date of publication. Important references not appearing herein should be called to the attention of the Illuminating Engineering Society, 29 W. 39th St., New York, N. Y.

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La vacillement de la lumiere dans les installations d'eclairage electrique (Abstract from Elektrotechnische Zeit., 13, 20, 27 Sept., 1917, t, XXXVII, p. 453)—

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TRANSACTIONS

OF THE

Illuminating Engineering Society

PART I -- SOCIETY AFFAIRS

VOL. XIII

DECEMBER 30, 1918

No. 9

COUNCIL NOTES OF INTEREST.

COUNCIL MEETINGS OF NOVEMBER 14 AND DECEMBER 12, 1918.

New Members.

Upon recommendation of the Board of Examiners, the following applicants were elected to membership:

One Member.

THOS. F. O'NEILL
Electrical Engineer,
Winchester Repeating Arms Co.,
New Haven, Conn.

One Transfer to Member.

WILLIAM T. BLACKWELL
Illuminating Engineer,
Westinghouse Lamp Co.,
Bloomfield, N. J.

Six Associate Members.

H. F. BARNES
Illuminating Engineer,
Edison Lamp Works of General
Electric Co.,
Harrison, N. J.

S. D. COREY
Manufacturer of Corey-Lite,
Coxsackie, N. Y.

ZOE NATALIE CORRAZ
Technical Assistant in Study of
Light and Illumination,
Electrical Testing Laboratories,
80th St. and East End Ave.,
New York, N. Y.

CARRIE E. HORN

Technical Assistant in Study of
Light and Illumination,
Electrical Testing Laboratories,
80th St. and East End Ave.,
New York, N. Y.

HARRISON R. JOHNS

Foreman,
Harvey Hubbell Co. of Canada,
E. Toronto,
Ontario, Canada.

H. E. SHELTON

Contract Agent,
Wilmington & Philadelphia Trac-
tion Co.,
834 Market St.,
Wilmington, Del.

One Sustaining Member.

PORTLAND RAILWAY, LIGHT & POWER CO.
Electric Bldg.,
Portland, Ore.
Official Representative:
Francis H. Murphy.

One Associate Member.

F. F. KLENK
Electrical Engineer,
Crown Cork and Seal Co.,
1501 Guilford Ave.,
Baltimore, Md.

Other Membership Changes.

The resignations of the following
were accepted:

Four Associate Members.

GEORGE P. SMITH, JR.
W. H. BLOOD, JR.
H. G. REED
J. MONROE BRICE

Two Sustaining Members.

ADIRONDACK ELECTRIC POWER CORP.
Glenn Falls, N. Y.
Official Representative:
W. A. Buttrick.

PHOENIX GLASS CO.
230 Fifth Ave.,
New York, N. Y.
Official Representative:
E. H. Peck.

Seventeen Associate Members.

ALAN BRIGHT
Carnegie Institute of Technology,
Schenley Park,
Pittsburgh, Pa.

E. C. BROWN
52 Vanderbilt Ave.,
New York, N. Y.

W. A. COX
Public Service Electric Co.,
Newark, N. J.

B. F. DECK
Welsbach Co.,
Gloucester, N. J.

CHARLES H. DRUMMOND
2255 N. Uber St.,
Philadelphia, Pa.

K. GIRDWOOD
Cooper-Hewitt Electric Co.,
8th and Grand Sts.,
Hoboken, N. J.

F. N. HAMERSTROM
Welsbach Co.,
Gloucester, N. J.

E. P. JONES
United Gas Improvement Co.,
20 Maplewood Ave.,
Philadelphia, Pa.

B. MULLIGAN
420 Cummings Ave.,
Chevy Chase, Md.

N. H. POTTER
Public Service Electric Co.,
Newark, N. J.

G. M. SANBORN
309-311 N. Illinois St.,
Indianapolis, Ind.

H. R. SMITH
Philadelphia Electric Co.,
7 and 9 Chelton Ave.,
Philadelphia, Pa.

P. F. SULLIVAN
Bay State Street Railway Co.,
245 State St.,
Boston, Mass.

M. F. PERKINS
Public Service Electric Co.,
Newark, N. J.

H. MCG. TUKESBURY
Welsbach Co. of New England,
16 Oliver St.,
Boston, Mass.

L. T. R. WARD
Public Service Electric Co.,
Newark, N. J.

W. F. WEADLEY
General Gas Light Co.,
Kalamazoo, Mich.

Four Members.

W. B. CLINE
Los Angeles Gas & Electric Corp.,
Los Angeles, Cal.

C. P. HOUGHTON
Los Angeles Gas & Electric Corp.,
Los Angeles, Cal.

H. F. KRANTZ
160 7th St.,
Brooklyn, N. Y.

A. W. YOUNG
Public Service Electric Co.,
Newark, N. J.

Reinstatements.

L. G. D. MORGAN
EDWARD G. PRATT
W. H. WOHNUS

Deaths.

Notice has been received at the General Office of the deaths of Parker C. Dolton, formerly connected with the Philadelphia Electric Co., Philadelphia, Pa., and E. E. Hulfish, also a member of that organization.

An obituary of the late H. E. Randall, Jr., will be found in another column in this issue.

SECTION ACTIVITIES.**NEW YORK.****Meeting—November 14, 1918.**

The 1917-18 Report of the Committee on Automobile Headlighting Specifications was the paper of the evening.

Owing to the lack of time given for discussing this paper at the twelfth annual convention, it was found advisable to present this paper in its entirety at the meeting of the New York Section. Considerable discussion followed the presentation, which discussions together with the report will appear in the next issue of the TRANSACTIONS.

Meeting—December 12, 1918.

A. L. Powell and R. E. Harrington have collaborated in the preparation of a paper "Light as an Aid to the Transportation of Material" which was presented at the meeting of the New York Section on December 12, 1918. Advance copies of this paper are procurable upon application to the General Offices. The paper and discussions will appear in an early issue of the TRANSACTIONS.

PHILADELPHIA.**Meeting—November 15, 1918.**

What resulted in a pleasant and instructive evening was the presentation of the paper by Ward Harrison, "Accessories for Industrial and Protective Lighting."

The different shapes of porcelain enamel reflectors, which are most largely used in current practice, were illustrated by lantern slides.

This was the first meeting of the Philadelphia Section for 1918-1919, inasmuch as the meeting scheduled for October could not be held because of the prohibition of all gatherings on account of the influenza epidemic.

CHICAGO.**Meeting—December 19, 1918.**

As this issue goes to press, word has reached the General Offices that Mr. M. Luckiesh will present before the Chicago Section on December 19th a paper entitled "Camouflage." Mr. Luckiesh is Chairman of the Committee on Camouflage of the National Research Council, and will give an illustrated lecture on the evolutions of marine and aerial camouflage which Mr. Luckiesh has accumulated by months of flying experience while on investigations for the government. He will describe his experiences and accompany the talks with many slides.

NEW ENGLAND.**Meeting—November 15, 1918.**

The first fall meeting of the New England Section was held at the Engineers Club, Boston, Mass., on November 15, 1918, at which time A. L. Powell presented the paper "Lighting of Cotton Mills."

The other speaker of the evening was Major Blair, U. S. A., on the staff of Major General Wm. Crozier, U. S. A., Commanding the Department of the Northeast, whose subject was "The Kaiser, Is he a Criminal under the Law?"

NEWS ITEMS.

Revision of Membership List.

Members of the Society are requested to aid in the revision of the Membership List. Council has authorized the printing of a new list and only through the co-operation of each individual member can this work be effectively executed. The card bearing a request for your present address and occupation no doubt has reached you and its immediate return is the best assistance the membership can lend to the early printing of such a list.

The Council has appointed a committee on the revision of the Constitution and By-laws, to recommend such modifications as meet present needs. Any member having suggestions to make in this connection is requested to forward them to the General Office or to G. H. Stickney, chairman of the committee.

Lighting in Wartime.

To obtain comprehensive and constructive information on lighting in wartime, covering aspects of wartime lighting economies, protective lighting, productive intensities, and the relation between light curtailment and accident hazards refer to the latest pamphlet issued by the Society, entitled "Lighting in Wartime." To manufacturers, central stations, and individuals this pamphlet carries the message and the need for proper lighting. Upon application to the General Offices, copies of "Lighting in Wartime" can be obtained at the cost to us.

Of interest to members of the Illuminating Engineering Society returning from war service, will be the action of the Council, which empowers the President to appoint a committee to assist

war service members to locate civil positions. This work will be in co-operation with the Engineering Societies Employment Bureau, formerly the American Engineering Service, which was the central body to which the Government and war working establishment looked to for engineers qualified for special branches of engineering service, both in military and civil walks. With the ceasing of hostilities, the Engineering Societies Employment Bureau, in co-operation with the several technical societies, is endeavoring to assist engineers returning from war work, to locate civil positions.

A movement has been started in Toronto to form an association for the purpose of furthering the interests of illuminating engineering and improving lighting conditions. H. D. Burnett and W. P. Dobson, both members of the Society, are the leading spirits. The association is rather informal as yet with no constitution, no regular meeting place and no regular membership fee. From Mr. Burnett, our Local Representative in Toronto, we learn that the requisite to membership is interest, directly or indirectly in the subject of illumination. This movement had been started in Toronto, before the World War, but unfortunately some of the leaders were called to active service, and the matter temporarily held in abeyance. With the evidence of the struggle closed, interest has again been revived, and the first meeting was held on November 5th at which time George C. Cousins, member of the I. E. S., presented a semi-technical paper, "Photometry and Its Application to Commercial Needs."

As Mr. Burnett expresses it, with the increase of interest in this new line of endeavor, he hopes in this way to

add materially to the membership of the I. E. S.

In the December 5, 1918, issue of the *National Civic Federation Review*, mention is made of the work of the Divisional Lighting Committee, of which Mr. L. B. Marks is Chairman.

Attention is called to the adoption of industrial codes by four states in the Union, prepared under the auspices of the Divisional Lighting Committee. Several other states at this time are considering the adoption of similarly proposed industrial codes.

In Part II of this issue on page 528, the Chairman of the Divisional Lighting Committee presents a statement covering the work of this committee.

A sister society has been formed in Japan, and we are fortunate to reprint here a news item covering the organization of the Illuminating Engineering Society in Japan.

I. ORGANIZATION OF THE SOCIETY.

During the year 1914, it was proposed by persons interested in the matter to organize a society for scientific research in connection with the illuminating engineering; but such a society failing to come into existence at that time, it was subsequently again planned to organize one in the early Summer of 1916 with the result that, at last the present society was formed on November 27 of the same year.

The promoters of the organization of the society consist of the following gentlemen:

Dr. O. Asano
Mr. H. Kodama
Dr. I. Nakahara
Dr. K. Tatsuno
Late Dr. I. Fujioka
Dr. S. Kondo
Dr. I. Namba
Dr. M. Tonegawa
Late Dr. I. Hirobe
Dr. H. Nagaoka
Mr. Y. Shinjo
Dr. G. Yamakawa

Assistants:

Mr. Y. Fukuda
Mr. M. Uchisaka

II. ENTERPRISES OF THE SOCIETY.

With a view to make the scientific research in connection with the illuminating engineering and of bringing it into a wide practical application among the public, the society is now carrying on the following enterprises:

(1) *Publication of the Transaction.*—The *Transaction* is being published quarterly, and contains speeches and essays by the members, extracts and news from the illuminating engineering world, and business reports and accounts of the society.

(2) *Lectures.*—Lectures are held at various places from time to time, to which the members of the society and others interested in this science are invited to publish the results of their researches, to speak of their experiences, or to discuss their opinions, etc.

(3) *Committee on Standardization of Electric Lamps.*—A committee on standardization of electric lamps was established in March, 1918, and its meeting being held every month, the matter is being carefully investigated.

(4) *Committee on Nomenclature.*—A committee on the nomenclatures relative to the illuminating engineering was established in July, 1918, and its meeting being held every month, the matter is being carefully investigated.

(5) *Prizes Offered on the Designs of Illuminating Apparatus.*—Public prizes for the designs of illuminating fixtures which will suit to the Japanese room of the middle class households have been offered, and the result thereof was published in the first week of October, 1918.

(6) *Historical Exhibition of Illuminating Apparatuses.*—A historical exhibition of illuminating apparatuses was held simultaneously with the above mentioned publication of designs.

(7) *Public Lecture in Illuminating Engineering.*—It is now in course of preparation to hold a public lecture in illuminating engineering.

(8) *Actual Measurement of Interior Illumination.*—With a view to publish the result in the magazine of the society,

actual measurement of intensity of illumination in the interior rooms of representative buildings is being carried on.

(9) In addition to the above mentioned enterprises, several other undertakings suitable for attaining the object of the society are being carried on.

III. MEMBERS OF THE SOCIETY.

The members of the society consist of the following four kinds:

Honorary members, being those who hold a high situation and enjoy a good reputation in connection with illuminating engineering business.

Supporting members, being those who support the principle of the society and give a material assistance towards the attaining of its object.

Regular members, being those who have been educated at a college of high standard, or studied the illuminating engineering science or other science having connection with it, or have experience in the illuminating engineering arts or other businesses having connection with them.

Associate members, being those who are engaging in the illuminating engineering works or have connection with such business.

When the society was first organized, the number of members was only 443, all of whom were regular members, although the society had canvassed about for membership in every direction among the societies having any connection with the illuminating engineering, such as those of electricity, gas, architecture, physics, psychology, sanitation, etc.; at present the number of members is as follows:

Supporting members	89
Regular members	537
Associate members	32

IV. OFFICERS OF THE SOCIETY.

There are one president, two vice-presidents and forty-six councillors in the society and managers are elected from amongst the councillors by mutual vote.

Present officers of the society are as follows (excluding councillors):

From 1916 to 1918.

President:

Dr. G. Yamakawa, Professor, Electrical Engineering College of the Tokyo Imperial University.

Vice-Presidents:

Y. Shinjo, Vice-President, Tokyo Electric Co.

Dr. I. Nakahara, Vice-President, the Tokyo Electric Light Co.

Managers:

Y. Fukuda, Electrical Engineer, Imperial Communication Dept.

T. Hatano, Vice-President, Dai Nippon Electric Lamp Co.

T. Kujirai, Professor, Electrical Engineering College of the Tokyo Imperial University.

R. Mitsuda, Electrical Engineer, Imperial Communication Dept.

T. Nomura, Electrical Engineer, the Tokyo Electric Light Co.

M. Uchisaka, Illuminating Engineer, Tokyo Electric Co.

Purely Personal.

Lieut. M. B. Hastings, associate member of the Society and secretary of the A. H. Winter-Joyner, Limited, Toronto, has been awarded the Military Cross. Lieut. Hastings left Canada with the 4th Canadian Mounted Rifle Battalion, but was later transferred to an artillery company.

GENERAL OFFICE.

We are anxious to learn the whereabouts of several of our members, who have evidently moved from their former addresses and have not advised the General Office of such changes. Below are the names of these members of the Society and their former addresses.

Information leading to their present locations may be forwarded directly to the General Office of the Society.

W. W. Cloud, Philadelphia Electric Co., 1000 Chestnut St., Philadelphia, Pa.

W. P. Devery, Philadelphia Electric Co., 7 and 9 Chelton Ave., Philadelphia, Pa.

G. G. Finley, Philadelphia Electric Co., 18th St. and Columbia Ave., Philadelphia, Pa.

E. E. Miles, 42 Pine St., New York, N. Y.

G. H. Guernon, Macbeth-Evans Glass Co., 143 Madison Ave., New York, N. Y.

Geo. H. Cook, Public Service Bldg., Kenosha, Wis.

H. M. Hafleigh, Lansdowne, Pa.

H. Nusbaum, Beacon Light Co., Chester, Pa.

OBITUARY.

Another death resulting from influenza has claimed H. E. Randall, Jr., a member of the Society. Up to the time of his death Mr. Randall was Electrical Engineer of the Shawinigai Water & Power Company of Montreal, Canada.

ILLUMINATION INDEX.

Prepared by the Committee on Progress.

An index of references to books, papers, editorials, news and abstracts on illuminating engineering and allied subjects. This index is arranged alphabetically according to the names of the reference publications. The references are then given in order of the date of publication. Important references not appearing herein should be called to the attention of the Illuminating Engineering Society, 29 W. 39th St., New York, N. Y.

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VOL. XIII

FEBRUARY 11, 1918

No. 1

A COLOR SYMPOSIUM.*

IN SIX PARTS.

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C. E. FERREE AND G. RAND,
BEATRICE IRWIN,
M. LUCKIESH,

IRWIN G. PRIEST,
H. C. RICHARDS,
LEONARD THOMPSON TROLAND.

PART I.

THE POTENTIALITY OF COLOR IN LIGHTING.

BY M. LUCKIESH.

Mythology reveals the fact that color impressed mankind before the beginning of recorded writing, and researches among the primitive races of to-day indicate that color influences the human organism early in the evolutionary progress of man up the ladder of civilization and intelligence. It appears that there are certain psycho-physiological effects of various colors innate in the colors themselves but the meager language of color which is definite to-day is a result partially, if not largely, of associations and usages. For ages, colors have played expressive and impressive roles in nature, mythology, poetry, ecclesiasticism, theatricals, painting, decoration, and architecture, and they have been associated with many purely utilitarian uses. Therefore, with the passage of time there have been added to the language of color, many symbolical usages with the result that the definite meaning of color is no longer confined to the psycho-physiological effects which may be innate characteristics.

* A series of papers prepared for the 1916-17 Correspondence Convention of the Illuminating Engineering Society, and circulated among members of the Society and others who were thought to be interested. This series was also presented before the New York Section October 11, 1917. Part III of the series was also presented before the Philadelphia Section, Philadelphia, Pa., Dec. 21, 1917.

However, the definiteness of this language is not extensive and there is the ever-present difficulty of determining the boundary between fact and fancy. This is made more confusing by persons possessing at best only a superficial knowledge of the facts of color who fail to distinguish between fact and fancy. In any contemplated employment of colors on a sufficiently large scale to provide an atmosphere or environment which affects those who come under its sphere of influence, it is essential to be able to separate the innate or fundamental psycho-physiological effects to which the individuals of a group, nation, or race are similarly susceptible from those aspects which are matters of individual taste. Taste is more or less a personal matter and therefore indeterminate because it depends upon the associations, experiences, and intellectual development of the individual.

In gleaning the knowledge of the expressiveness and impressiveness of color from the many indirect and unassociated sources of information it is easy to go astray because of the many influences or factors to be considered. It is senseless to adopt a certain color-effect for all occasions which from a superficial view appear similar just because the result is satisfactory in one case. The environment and the spirit of the occasion may vary greatly. Further, red is a signal of danger but it is only recognized as such in its appropriate environment. Combined with these many aspects are the problems of esthetics and harmony of color which make the problems of color in lighting extremely intricate if the lighting specialist aims to tap the potentiality of color and to obtain results which have a sound basis for existence.

Some so-called artists brush the whole matter aside by relying on their *feelings* or sensibility. But we cannot justify the ignorance of facts and it is interesting to note that great artists are first great scientists so far as their work is concerned. There is nothing supernatural or superhuman in art; the mysteries are merely unknown or unexplained facts. Furthermore, it does not diminish our appreciation of the beautiful and the impressive to become acquainted with their philosophy and to solve their *mysteries*.

In this introductory paper the discussion is designedly confined to generalities because a treatment of details would lead far afield owing to the necessity for much qualifying material. The ma-

terial of the language of color cannot be treated briefly; but it has been compiled for presentation elsewhere.¹ But the lighting specialist may accomplish much of his own accord by utilizing the coldness, warmth, and neutrality of colors which may be obtained in any degree by a proper selection of hue, tint, and illumination intensity. He may study the symbolic uses of color and gradually extend these to lighting. There is no reason why we should not *paint* with light; in fact, this is an excellent description of an artistic lighting effect. In applying tinted illuminants in this manner, the lighting artist has in hand a medium much superior in expressiveness, adaptability, and variety, than pigments, and the principles of esthetics and harmony of color apply equally well to illuminants and pigments.²

A few common examples may illustrate the use of colored lights for their psycho-physiological effects. Red is characteristically a stimulant or excitant. It has been shown that more work of a certain nature was done by subjects under this illuminant in a given time than under ordinary light. However, it is not recommended for constant use any more than stimulants taken internally. By decreasing the saturation until a delicate tint is obtained perhaps just the required enlivening effect may be obtained for a given purpose. For example, a light tint or reddish purple, commonly called rose, is delightfully stimulating and may be suitable for certain occasions in dining and living rooms or in ballrooms and restaurants, though this hue is not suitable for a quiet study.

Yellow and orange are mildly stimulative and best described as warm colors. It is interesting to note that tints and shades of yellow are the colors most widely used in interiors. Perhaps this usage has arisen from a desire to make the interior cheerful and inviting. Incidentally, the color of most early illuminants has been a warm unsaturated yellow. These influences have naturally led to a desire to alter modern illuminants to a warm yellow color. However, the mistake is made in using amber for this purpose for its hue is greenish yellow which is not generally pleasing for illumination. It is possible to obtain a warm yellow both in glass and in permanent superficial coatings so there ap-

¹ "The Language of Color" (in press), Dodd Mead and Co.

² "The Lighting Art," McGraw-Hill Book Co., 1918.

pears to be no necessity for using amber except for a spectacular purpose. There is plenty of evidence which shows that a light tint of greenish yellow is an unpopular color. Sometimes in the summer, interiors in which the illuminant is of a deep yellowish hue are psychologically uncomfortably warm.

Green is most generally characterized as a neutral color perhaps due to continued adaptation to large areas of this color in nature. It has value for illuminating purposes in the more elaborate artistic schemes of lighting.

Blue is a cold, sedate, and even depressing color. It is often considered to possess the attributes of serenity and harmony doubtless due to its occurrence in the sky which is certainly the acme of serenity when of a clear blue color. Its dominating presence in many landscapes perhaps has led to the bestowal upon it of the attribute of harmony. The coldness of blue or blue-green is often undesirable, but proper tints of these colors may be utilized to advantage. For example, how much more inviting and comfortable a theatre appears in midsummer when illuminated by light rays of a delicate blue-green tint. There are many such applications for the coldness of certain colored illuminants. In most of the applications of colored illuminants for general lighting, tints that are felt but scarcely seen are more generally desirable than illuminants giving purer colors although the latter have decorative value.

A knowledge of the general preference for various colors may be helpful to the lighting specialist. Similarly the attention-value of colors may find suitable applications. Although there are some data available pertaining to these aspects, the psychologist must be prevailed upon to provide more. This is also true of the more utilitarian aspect of colored light, for at the present time the lighting specialist does not possess enough definite information to enable him to specify colored illuminants for various activities in which they may possibly be used to advantage. For example, certain kinds of work may be done more rapidly and satisfactorily under colored illumination than under ordinary illumination.

Colored light is responsible for certain physiological effects and therefore may eventually find a wider use in medical treatments. The psychological effects of illumination by colored light may

also be destined to an extensive use in the treatment of mental disorders. The opinions regarding the relative glaring effects of different colored lights vary considerably and therefore the physiologist will be of service in investigating this problem among many others.

The physics of color is the most thoroughly explored aspect of the entire science of color and the physicist and the chemist are prepared to furnish many colored illuminants, by developing permanent filters for use with modern light-sources. Researches in colored media are complete enough to furnish most of the colored illuminants which may be demanded. Artificial daylight has been produced, and the old illuminants have been simulated by means of permanent colored filters, various other illuminants have been developed for special purposes and physical and chemical data are available for the development of many other filters.

There are some aspects of the physics of color which remain to be developed. For example, no rational system of color-notation exists and a method of color-photometry has not been standardized. The latter has been studied chiefly with a view toward standardizing a method of photometry for ordinary illuminants, but those interested in color are in need of a suitable method of photometry for colors in general.

Excellent progress has been made toward standardizing a scale of color for illuminants on a temperature basis. Many kinds of colorimeters are in use which indicate the lack of standardization in colorimetry. This Society has adopted a portion of the terminology of color which it is hoped will be considered by various scientific as well as artistic bodies interested in the subject. There is a general looseness in the use of color-terminology in the discussion of color which is confusing and deplorable. May we not appeal to this body for a more careful consideration of these matters?

Colored illuminants are now being used for many special purposes but there is much work to be done in order to be sufficiently sure of the ground to warrant further developments in certain promising fields. As new developments appear, the scientific uses of colored light will be extended. For example, there are some unanswered questions pertaining to colored illuminants for signalling purposes and for various visual activities. There

appears to be a necessity for a more general knowledge of the use of colored glasses for protecting the eyes. At present, unproved claims are in some instances the basis of sales propaganda for such glasses. This energy might better be expended in providing tests of such devices.

Colored light is important from the standpoints of dye-testing, photographic processes, visual acuity, retinal sensibility, signalling, microscopy, plant growth and development, many chemical processes, and in the vast field of psychology and physiology, much of which is unexplored. In advertising, in the theatre, and in other fields, colored light possesses unlimited potentiality in artistic and spectacular effects. For example, imagine the lighting of the Panama-Pacific Exposition without its magnificent effects of color and the possibilities of colored light in a single field will be evident.

Every problem of lighting is perhaps solved when distribution, color and intensity have been properly related. A few of the aspects of color in lighting have been mentioned with the aim of indicating the magnitude of this field. It appears that the lighting scientist of the future will find the horizon of his field of activities greatly extended and the lighting artist has before him great opportunities for *painting* with light. But it is unnecessary to await some future day for the potentiality of color in lighting is ever-present and opportunities for drawing upon it are omnipresent.

PART II.

COLOR FROM THE PHYSICAL POINT OF VIEW.

BY H. C. RICHARDS.

Let me first express my appreciation of the honor which your society has done me by asking me, who am neither an engineer nor (as the sequel will show) illuminating, to take part in this symposium on color. I must also compliment your committee on the selection of a subject of such great interest from so many different points of view.

The task is assigned me of introducing the subject by considering its physical aspect. Now at first sight this would seem to be a simple matter. For we are told that color, being a sensation, does not exist in the physical world about us, but is a subjective phenomenon. I might therefore at this point gracefully close and yield place to my successors. But this might be a dangerous surrender of ground, since the phenomena of color, excluding exceptional cases of purely subjective color, as when we *see red* (or feel blue), are closely co-ordinated with the physical stimulus. It is therefore appropriate that a discussion of color should be prefaced by a consideration of the laws and properties of radiant energy which are related to the assigned topic. However, this would open up for discussion almost the whole field of optics, at least as far as is included in the visible spectrum. Such a program is obviously impossible to undertake in the limitations of such an occasion as this. I shall therefore confine myself to some remarks on the physical phenomena attending the production of light of various colors.

The color of a light may be expressed in terms of its hue, brightness and saturation; or we may define it by the relative amounts of three standard colors, as red, green and blue, which must be added to produce the same impression on the eye. But these are more or less subjective definitions. From the physical point of view the character of a light (*i. e.*, its color) is determined by the distribution of energy among the different wavelengths in its spectrum. The translation of this information into terms of color sensation is effected by the study of the effect of

light of various wave-lengths in producing the fundamental color sensations.

It should be noticed however that the converse is not true, *i. e.*, it is not possible to infer without ambiguity the constitution of a light from observations of its color, since various combinations of spectral constituents will yield the same color sensation. Thus a mixture of light from the red and green portions of the spectrum may be made to produce a yellow sensation matching a spectral yellow. And the sensation of white may be produced in many different ways.

There is here a contrast between the sister sciences of optics and acoustics. The characteristics which distinguish sounds—pitch, intensity and quality—correspond completely to the three physical properties of a wave—length, amplitude and form or complexity, while in optics the co-ordination of the properties of hue, brightness and saturation to the corresponding physical properties is imperfect. The reason for this doubtless lies in the mechanism of the organs of sensation. The ear perceives sounds by a process of selective resonance, waves of different length affecting different parts of the organ, while this is not true of the eye. But to pursue this thought further would lead us into forbidden territory.

Turning to the physical laws determining the color of a light source, we find two classes of illuminants: Those having discontinuous and continuous spectra. To the former belong luminous vapors, to the latter incandescent solids and liquids. The classes differ not only in their physical structure but also in the method by which the luminosity is produced; for while continuous spectra are produced by heat alone, the production of a discontinuous spectrum requires for the most part electrical or chemical action, though in some cases heat is used to stimulate such action.

Sources giving discontinuous or bright line spectra furnish us with the most brilliant and varied colored lights. These are produced by salts volatilized by a flame or by the electric discharge through rarefied gases. Here we have all degrees of complexity, from light of but one wave-length, as in the yellow of sodium or the green of thallium, to that of mercury vapor where there are a half a dozen constituents, and so on to more complex cases such as that of iron with thousands of lines. When the wave-lengths

present are predominantly in one portion of the spectrum, the light will be more or less richly colored, as for instance in the brilliant red of the strontium flame or of the neon vacuum tube. When the energy is more or less uniformly distributed through the spectrum the light becomes whitish in character, as with the Moore carbon dioxide tube or even the mercury vapor light. The relations between the wave-lengths present in a given spectrum are of great interest to physicists and are being assiduously studied as a means of obtaining information as to the structure of the radiating atoms, but they are of no importance to the present discussion.

Sources of this class have long been used in the production of colored fires, etc. The only cases in which they have found extensive practical application as illuminants has been in the mercury vapor arc and the Moore carbon dioxide tube. They are also used in the colored or flaming arcs produced by impregnating the carbons with various metallic salts. In the latter case the effect is combined with the continuous spectrum of the incandescent carbon. Even in the ordinary carbon arc the line spectrum of the carbon vapor and of impurities is present, though it plays a subsidiary role.

By far the greater number of illuminants belong to the class of those having continuous spectra, among which we must include our most important or standard light—that of the sun. In these the predominant part is played by temperature. It is familiar to us all that as the temperature of a body is raised it begins at about 500° to emit light which changes in color as the body becomes successively red hot, yellow hot and white hot.

The laws of the distribution of energy in a radiating body, *i. e.*, of its color, have long been of interest from the theoretical as well as the practical standpoint. To Kirchoff a half century ago we owe the law known by his name that at a given temperature the light emitted by a body is proportional to its absorbing power, and that this is true not only for the light as a whole but for the separate constituents. Thus good absorbers radiate more at the same temperature than good reflectors, and a body which selectively absorbs a part of the spectrum will have a greater emissive power for the same region. A familiar illustration of the law is the almost non-luminous bead of sodium hypophosphate in the

blowpipe flame, due to its high transparency, while the supporting platinum wire is brightly incandescent.

Caution must be used in interpreting this law, for the absorbing power of a body is a function of its temperature, and bodies which are selectively absorbing, *i. e.*, are colored at ordinary temperatures may lose this property at the temperatures necessary for incandescence. We need not therefore infer for, example, that red glass and blue glass will necessarily emit light of markedly different quality when heated to incandescence. The opposite effect is seen with the Welsbach mantle which is white at low temperatures but when heated (due to the traces of cerium), becomes increasingly absorbent of blue light and therefore takes on a yellowish tinge. Accordingly the mantle emits light which contains a greater proportion of blue to red light than other illuminants at the same temperature.

The law of Kirchhoff also leads us to infer that a perfectly black body, *i. e.*, one which will absorb all incident radiation, will at a given temperature emit more light than any other body, and that the amount of each frequency emitted by such a body is a definite function of the temperature and of the frequency. This complete or black body radiation has played a prominent part in both theoretical and practical investigations. Thus on the side of theory it has led not only to important and interesting laws but has formed the starting point of a new theory—the quantum theory—which is modifying our fundamental conceptions as to the nature of energy. On the practical side it gives us a standard of radiation independent of the various properties of different kinds of matter, which can be accurately reproduced and which, as in pyrometry, can be used as an indicator of temperature.

The laws of black radiation are summed up in the formula of Planck which states that the radiation of a given wave-length λ and temperature (abs.) T is given as

$$E_{\lambda} = \frac{C_1}{\lambda^5} \cdot \frac{1}{e^{\frac{C_2}{\lambda T}} - 1}$$

where $C_1 C_2$ are constants. As far as the visible spectrum is concerned one may use the simpler formula of Wien:

$$E_{\lambda} = C_1 \lambda^{-5} e^{-\frac{C_2}{\lambda T}}.$$

Another important result deduced from theory and confirmed by experiment is known as Wien's displacement law. This shows us that while the energy emitted increases with temperature the increase is more rapid in the shorter wave lengths, so that the wave-length where the energy is a maximum is inversely as the absolute temperature, or

$$\lambda_{\max} \cdot T = \text{const.}$$

This law, which is accurately followed by black bodies and qualitatively by other incandescent bodies, explains how the color of a luminous body changes as the temperature is raised. At first only the red waves are produced in sufficient amount to become visible but at higher temperatures the shorter increase in relative prominence and the light while increasing becomes whiter and whiter. The advantage of high temperature in illuminants is therefore not only in obtaining greater efficiency by increasing the proportion of visible radiation but also in approaching closer to the quality of our normal illuminant—sunlight. That we are still at some distance from attaining our ideal by this means is evident when we consider that the quality of sunlight approximates to that of a black body at 5,000°.

The quality of the light emitted by a source is not always the quality with which we are concerned. We see this even in the case of sunlight; for while the temperature of the sun is about 7,000°, its light is modified in passing through its own atmosphere and ours until, as before mentioned, it approximates to that emitted by a black body at 5,000°.

The light of a source is usually modified by transmitting it through a selectively absorbing medium such as colored glass. This subtracts from the light its different constituents in varying proportion so as to modify its spectral quality. By this means one light source may be made to produce the same effect as another. Thus amber glass shades may be used to "tone down" the whiter electric light to the quality of lamplight; and the last few years have seen the production of "daylight glass" which modifies the light of a tungsten bulb to the approximate quality of daylight. For accurate reproduction of light of one quality by that of another it is necessary to have a screen or rather a filter whose transmitting power for each wave-length is proportional to the ratio of the intensities of the sources for that wave

length. It may perhaps be worthy of remark that even when a suitable medium has been found, the result will not be correct unless the proper thickness has been selected. Thus if a glass of given thickness will transmit twice as much blue as red, one of twice the thickness will transmit four times as much.

Another but less usual method of modifying the color of a light is by selective reflection. We have recently had an instance of this in the gilding of the reflectors of automobile headlamps to produce a yellower and supposedly more penetrating beam. In interior lighting, especially in indirect lighting, the color of the light is often modified by reflection from the walls so that its quality may be quite different from that of the original source. Even daylight has been found in summer to be slightly tinged with green by mixture with the light reflected from foliage, while in winter or over the sea the effect is absent.

A light of given quality may also be produced by combining sources of different kinds. This method has been used to produce artificial daylight. This is also the basis of some processes of color photography, where any color is imitated by the addition in various proportions of red, green and blue lights.

The color of an opaque object depends on two factors: The quality of the light which falls upon it, and the relative amounts of the various constituents of the light which are reflected to the eye. Objects therefore appear of different colors when differently illuminated, and to preserve color values it is essential that the spectral distribution of the illuminant be kept unaltered. It is this that has produced the stimulus to the production of artificial daylight, which to be completely successful must not only give the eye the impression of daylight, but throughout the spectrum must approximate to the distribution found in the real article.

I have not spoken of the production of colors by interference or diffraction, as these methods, though instructive and interesting from the physical point of view, have no important practical applications. For the same reason I have not alluded to fluorescence, which in some cases modifies the color of an object, but which, except in the use of the fluorescent rhodamine screen to introduce a red component in the light of the mercury arc, has been little used in practical lighting. The scattering of light by suspended particles and even by the molecules of the air, which

produces the blue of the sky and affects the quality of daylight, must also be left without further allusion, and other color phenomena of interest from the physical side must yield to the prescribed limitations which I fear have already been exceeded.

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contain much interesting material. The character of the solar spectrum is treated in

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PART III.

COLOR IN ILLUMINATION.

BY BEATRICE IRWIN.

As indicated by the title, the subject of this paper is "Color in Illumination." Before discussing this single aspect of color, however, it is desired to dwell briefly upon another and distinct phase, which is included in what I call "The New Science of Color."

Observation and experiment have led to the conclusion that there are three fundamental scales of color, which react respectively on our physical, mental and nervous systems. These I have named the *physical*, *mental* and *nervous* colors. Each of these is divided in turn, in accordance with its affective values, into sedative, recuperative and stimulant colors. Whether we are aware of it or not, color always falls within one of these three groups and always affects us in one of these three ways.¹ I have attempted to represent these subdivisions of color in the accompanying chart. (Fig. 1.)

Red has been called a stimulant, blue a sedative, and green an exhilarating color. I contend that red can be a sedative, blue a stimulant, etc., according to the composition of the red or the blue, or according to its combination with other colors. If we can determine and appreciate the psychological as well as the physiological value of a color we can utilize it to an extent hitherto unknown. This theory I have submitted to laboratory as well as other tests.

Once we realize that the terms red, blue, green, etc., are only symbols for long ranges of vibratory phenomena which we must classify and utilize with a new nicety and thoroughness, we shall have taken the first step toward realization of the full value of color as an influence in our lives. If this new language of color is to conduce to the comfort of all, it will have to establish its credentials through universal as well as individual channels, and it will have to prove its industrial as well as its esthetic and scientific value.

¹ This subject is elaborated in my recent book, "The New Science of Color," whose chief aim is to liberate color from the purely objective and ornamental status that it has held in our past consciousness and expression.

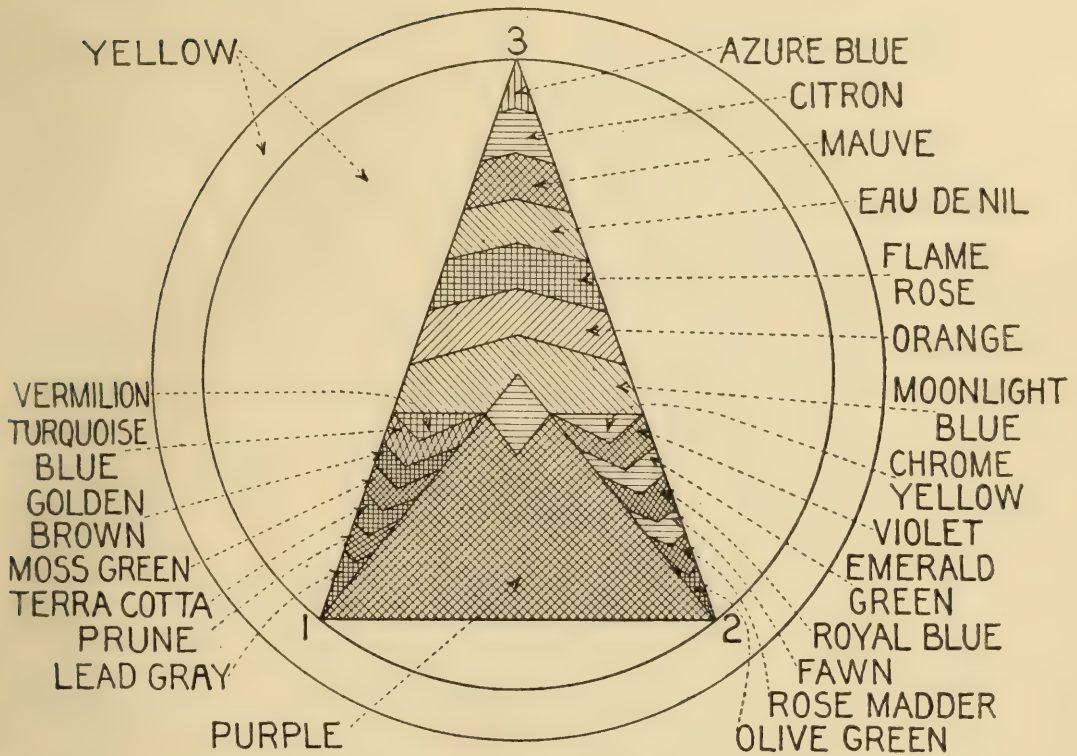


Fig. 1.—In this chart the golden circle represents *ether*; the violet space, *Earth*; the central diamond space, the *head of man*: (the upper point of the diamond representing his *spiritual eye* and the left and right points respectively representing his *left* and *right eyes*). Figs. 1, 2 and 3 represent respectively the *physical*, *mental* and *nervous* systems with their subdivisions of *sedative*, *recuperative* and *stimulant* colors.

THE THREE COLOR SYSTEMS WITH THEIR SUBDIVISIONS.

1. The Physical	2. The Mental	3. The Nervous
Sedative	Sedative	Sedative
Lead gray	Olive green	Moonlight blue
Prune	Recuperative	Recuperative
Terra cotta	Rose madder	Orange
Moss green	Fawn	Flame rose
Recuperative	Royal blue	Stimulant
Golden brown	Emerald green	Eau de Nil
Turquoise	Stimulant	Mauve
Stimulant	Violet	Citron
Vermilion	Chrome	Azure blue

At last color is coming into her own through many channels, and while realizing as I do, their respective significance, I do not hesitate to say that one of the greatest opportunities for scientific color expression lies in the hands of the illuminating engineer, for if the physician and psychologist can determine the science of the affective value of color, the illuminating engineer can supply that light of any desired hue, and through this opportunity he can develop a new field of achievement.

But in order that he may avail himself of this opportunity he must train his eye and his whole organism to this broader vibratory conception and realization of color.

The color-sense, like all senses, is dependent upon a definite but gradual education, and while it is more developed in some than in others, it is certainly capable of coherence in all, and it is to the achievement of this coherence that the new science of color aims.

An increased color sensibility, with a lack of coherence is what all color expression suffers from at the present moment. In this color language we have found a new voice, but we are trying to sing songs before we have formulated syllables—or practiced our scales. The students of color-science are thinking and speaking of color in the psycho-physiologic terms individual to itself which my chart provides, and which aim at a clearer understanding upon a hitherto vexed question.

In this century any message that claims to be universal must fulfil exacting and multiple conditions, because this is the glorious age of co-operation, of mental democracy and of the intermingling of *industry, art, science and religion*. History has never recorded any epoch in which there was such an alliance and interpenetration of activities, not for the purpose of individual enjoyment, but for the general welfare. I have traveled once and a half around this radiant world, and of all the countries visited, America appears to me to be foremost in demonstration of this co-operative universalism. The theoretical philosophies and cautious enterprise of other countries pale before the ruddy and solid proofs of progress that are embodied in your vast cities, your expositions, your splendid libraries and colleges, and in your representative homes, which all proclaim the marvels of light

and the longing for its further utilization and understanding through this mobile and ardent medium of color. Surely then it is not only well, but essential that we should employ some specialized classification of a phenomenon that we are expressing so freely.

For, fundamentally this growing need and use of color, and the increasing number of persons who are explaining and demonstrating its life, are only so many statements of the fact, that having battled with nature's coarser forces and expressed their conquest through graven images of metal, wood and stone, the race is now turning to the conquest of the finer forces which are collectively expressed in such words as light, electricity, vibration and color.

I am therefore happy to report to you that this new and broader aspect of color is finding more numerous adherents among psychologists, artists, astronomers and craftsmen.

Turning now to color in illumination, we may premise that the principal purposes of illumination are "Utility," "Beauty" and "Hygiene." Each of these may be promoted through a discerning and discriminating use of color, and the demand for color in illumination is a proof of our need for specialization in this application of light. I can foresee the creation of harmonic and mobile installations that will vie with nature's rhythmic distribution of light, which is so marvelously adapted to man's mobile requirements, for it is contrary to cosmic law that the human organism so pulsating and plastic in its essence, should be subjected to a monotonous lighting. How would a plant be affected I wonder were it subjected to the same degree of light continuously?

Once the principles of color-science have been mastered, half a dozen decorative schemes can be created by the use of adjustable screens, or textile linings for globes, but these linings should not fatigue the eye with useless design. In lighting, as in other channels, the liberation of color from conventional design is an essential point because our perception of vibratory color values is impeded by our perception of form. In my decorative work I advise diffused semi-indirect lighting for the first or general installation, and either lamps, side brackets or globes sunk in the wall for what I call special or color installation. Let us consider these installations in detail.

The general installation may with esthetic propriety lay more stress upon its fixtures which have a permanent decorative value in the interior, but these fixtures should also be selected in harmonic correspondence with general color environment. How often one sees a charming little room vulgarized by the introduction of a massive, pretentious brass or bronze lamp that is utterly incongruous with either the volume of light generated or the textiles illuminated. My attendance at various electric exhibits has shown me that considerable attention is still needed in this accessory branch of illumination. The general installation should be tinted either to heighten or lower the whole vibratory color values of the room, but this tinting should be delicate and unobtrusive, its aim being to create atmosphere rather than to focus attention. This is the function of the second, or color installation, and in this case the fixture should be as nearly invisible and as unimportant as possible, so that the impression received may be from the color itself, and it is best to express such light motifs in the natural recesses of shadow, or if such recesses do not exist in a room, we can create them by various artificial means. For this purpose I have used masses of silk (which has a high reflective value) around special installations.

The sunken globes to which I have referred were also originated by me for the purpose of creating mobile color expression in the interior. Set in the wall under glass ledges, their brilliance gives life to the hollowed niche in which is set the color screen which they illumine. These screens, which I am painting on parchment, are varied in form, can be changed at will, and are restful and effective. The electric current operated in connection with them can have several degrees of intensity, which further affects the color values of these screens. In large halls or ball-rooms such effects could be used with great decorative value in conjunction with pools of colored light in the floor under glass translucences.

When people become more acquainted with the hygienic value of colored lights possibly they may insist on these installations with as much stress as they now lay upon ventilation. Compare our modern windows with the slit-like apertures of the middle ages, and notice how the race demands light as it progresses. Now, from quantity we are advancing to quality, and color-

science can teach us to differentiate in this all-important question of the degree and nature of the lighting system in our dwellings. Unless in stores, where matching is a necessity, I think that the daylight system of illumination is a source of eye strain and nervous exhaustion. Just as inadequate lighting is responsible for eye strain in some cases, so over-lit rooms are responsible in other cases for more neurasthenics than the average physician is aware of. Color-science suggests that every building shall have two systems of illumination for alternate, but not simultaneous, use. The first installation shall fulfil practical demands, preserving the general conditions necessary for ocular hygiene, but avoiding any pronounced color or decorative effects. For example, in a dining-room or library, for general purposes, there should be a discreetly tempered luminance graded harmonically to the vibratory color values of the room, but in addition to this there should be decorative motifs of light which have a definite color purpose and value, and this installation could be operated as occasion demands.

To preserve color-balance a room worked out in sedative color scale should have recuperative values in its first, and stimulant values in its second installation. Do you notice that I purposely avoid the terms "utilitarian" and "decorative," because I feel so strongly that in reality these terms are one, the greatest use always underlying the greatest beauty, the needless distinction between these terms being accountable for most of our errors in color expression.

For example, a living room may be worked out in sedative gray with first installation of diffused lighting in recuperative rose, and second installation in recuperative orange, stimulant green and mauve. Once the key of this new color classification has been mastered, endless hygienic and esthetic combinations can be worked out.

It is quite possible for a lighting system to possess color hygiene without possessing any aesthetic value, but it is the aim of color-science to combine beauty with use in a very high degree. A few models demonstrating these principles can be seen at the Edison Exhibits on Irving Place, and other models are in view at the Color Science Centre on 57th Street. The object of this talk has been to prove that a co-operation between color-science

and illuminating engineering could considerably augment the three fundamental purposes of illumination, namely, utility, beauty and hygiene.

We could co-operate to bring people to realize the physical benefit and nerve repair to be obtained from mobile lighting. They might learn to vary the color screens in their rooms as they now vary the hanging of pictures. Indeed these decorative illuminations may take the place of pictures in many homes where it is not possible nor suitable to collect antiques. In the future these first expressions of a new art science may themselves be called "antiques!" Who knows, save Time, that strange wizard, who doles out the mysteries of space no sooner than we are ready to receive them?

I have always felt a strong analogy between the American and the Greek Republics, for the great American public is as vital as the great Athenian public was in its demand for variety and beauty in every expression of life. Therefore, with ardor I commend color-science, and I invoke the co-operation of the illuminating engineers, for whose present attention I am most happy and grateful.

PART IV.

THE PSYCHOLOGY OF COLOR, IN RELATION
TO ILLUMINATION.

BY LEONARD THOMPSON TROLAND.

COLOR AS A FORM OF CONSCIOUSNESS.

When the committee requested me to present a paper on "The Psychology of Color," it seemed to me that their phraseology was redundant, since from my point of view color appears to be a psychological fact, and a psychological fact only. The word "color," as it is used in popular, as well as in psychological discussions, refers to one of the fundamental qualities out of which our every-day experience or consciousness is made up; it is the basic stuff or substance of our visual awareness. The world of seen space, out into which we look, presents itself to us at each moment, as a pattern of colors and luminosities, arranged in three dimensions. This world of immediate visual consciousness, freed of the physical interpretations which our laboratory science thrusts upon it, is a subject matter of psychology, and only in this experiential world, so far as we know, does color exist.

Color, considered as a fact of immediate consciousness, must of course possess causes or conditions, and the science of color is as a matter of fact, more concerned with these conditions than it is with color itself. Thus we know that the normal experience of color in any individual awareness depends upon the stimulation of the eye with radiation comprised of a limited range of wave-lengths, it depends upon the response of the retina, upon the excitation of the optic nerves, and upon the activity of certain parts of the brain. Color thus has its physical and its physiological bases, but these are not themselves color, nor are they colored; and we should be very careful not to confuse them with color.

I have noticed a tendency to employ the word color in studies which deal purely with the objective properties of radiation, and I believe that this usage is undesirable because it conduces to a confusion of issues which really should be kept separate. Planck, for example in his discussion of temperature radiation, constantly

uses the word color as a synonym of wave-length. The greater fraction of the radiant wave-lengths with which his theory deals do not even have the power to excite color when they strike the eye, but even those which do possess "visibility" are simple ethereal undulations or electro-magnetic pulses, and not color. The "black body" radiation curve of an incandescent substance does not *constitute* a color, but merely represents a group of physical stimuli, which when applied to a normal visual organism will *generate* a color.

The confusion of color with the physical stimuli which usually produce it might be pardoned if the relation between actual color and optical stimuli were constant. As a matter of fact the relation, or relations, are far from being rigidly fixed. *Apparent color* is a function of a large number of variables, only one of them being the wave-length constitution of the radiation which some object transmits or reflects, or which strikes the retina. Physically, the "color" of rosaniline or methylene blue, is a constant, as it depends upon the chemical constitution of the substances, but the qualities which we experience when we look at these dyes depend not only upon the nature of the radiation which impinges upon them—whether it be "tungsten light" or "daylight"—but also upon the state of adaptation of the eye, the contrast conditions, the visual "type" to which we belong, and even upon what we expect or are accustomed to see under the given conditions.

An illustration of the practical importance of these psychological and physiological variables which influence experienced color can be found in connection with the new "daylight" lamps. If the purpose of these lamps is to reproduce at night the color experiences of daytime, it is certain that we cannot always accomplish this result by supplying radiation identical in wave-length composition with sunlight. A show window illuminated by strict artificial daylight, if set in an environment of ordinary "tungsten" or even "nitrogen tungsten" light appears distinctly bluish and cold. And it really is bluish and cold, so far as these terms have any meaning. The color is a result of the reaction of our psycho-physiological organisms, and in attempting to reproduce the color world of our daytime experience, contrast is a variable often more important than wave-length constitution.

Similarly, the state of chromatic adaptation or "tuning" of the visual system must be taken into consideration. If we come suddenly from the "yellow light" of our common artificial illuminants into daylight, artificial or real, the latter will seem unnaturally blue, because the exposure of the eye to the yellow light has raised its relative sensibility to blue. It is not quite correct, moreover, to say that this blueness is an illusion, and consequently to neglect it as of no practical importance. The actual color quality of our experience *is* blue, whatever may be the constitution of the radiation which is falling upon the retina. This radiation itself has no color at all. If we neglect the level of chromatic adaptation of the eye, in attempting to reproduce the daylight experience, we are passing over a fundamental variable in the equation which determines such experience. Such an effort would be like trying to regulate the pressure of a confined gas merely by changing the volume of the vessel in which it is contained, without considering possible variations in its temperature, which might result from the volume changes themselves.

It is of course true that if we pass from a yellow-illuminated environment into one which is flooded with true daylight, the bluishness which at first was so apparent, rapidly wears off. But this change follows an asymptotic curve of decay; it is never quite complete, and as time goes on the change occurring in each moment becomes less and less. This asymptotic law of color adaptation has many lines of practical application, some of which at first sight may seem logically opposed to each other. In the first place, it implies that the residual effects of the exposure of the retina to "colored light" will persist for a long time. There is good empirical evidence that this persistence increases with the intensity and duration of the exposure. If we have spent an hour in distinctly "yellow light" and then enter a room illuminated by daylight, the bluish appearance of things may continue for a relatively long time. The same effect is produced, of course, as a result of wearing amber glasses. Persons who use these glasses habitually, as for example in motoring, more often complain of the bluish quality of ordinary daylight than do persons who have never worn yellow lenses.

According to Hering, common daylight is psychologically slightly yellowish. If this is true it means that throughout the

day our visual apparatus is being strongly adapted to yellow, so that if we were suddenly to be shown a true white, it would appear somewhat bluish. Just what a true white is, physically, we shall consider below. But if the rod-cone or duplicity theory of vision is true—and it is the best-substantiated hypothesis in the whole field of sensory psycho-physiology—the quality of rod or twilight visual experience should be entirely achromatic. Night vision should give us a chiaroscuro of pure grays. Yet it has been asserted repeatedly that rod vision gives us a field which is slightly bluish. König considered this appearance to be so striking that he relegated blue vision to the rods entirely, and said that the rod-free fovea of the retina was blue-blind, a statement which is positively erroneous. The most reasonable explanation of the blueness of night vision with the rods would seem to lie in Hering's belief that sunlight is psychologically or physiologically yellowish. If, throughout the day, we are being adapted to yellow, the blue after-effect of this exposure should be expected to combine with the neutral gray of evening vision, making the latter somewhat bluish and cold.

Perhaps the most pervasive, if not the most fundamental principle of psychology is that of association, and it has been clearly shown that the workings of this principle can not only modify our imaginations, but can alter the quality of our perceptions and sensations. Long and constant experience has caused us to add to the actual physical data of evening vision a certain amount of blueness, which is subjective in its manufacture but which nevertheless forms an integral part of our visual consciousness. To a certain extent it may be true that simply because we are aware that it is evening, we subtract yellow and add blue to every color which we see, just as we subtract red from a snowy mountain peak illuminated by the setting sun, and thus see it still as white and not as pink snow.

This adaptational and associative blue of evening may then be a factor which should always be taken into consideration in planning artificial lighting which has definite color aims in view. Psychologically, the distribution curve of daylight from an artificial illuminant, may fail to reproduce the color world of daytime experience. Even under the most favorable conditions of contrast and adaptation, such a stimulus may continue to give us

a cold and unnatural feeling. For this reason it is quite likely that the common "daylight" lamp, which is a compromise between true daylight and efficiency, may in fact come closer to the reproduction of actual daylight experience than would the strict photometric daylight.

To a person who does not appreciate the importance of association and expectation in determining our experience, it may seem absurd to suppose that a maintenance of the wave-length constitution of daylight in evening illumination, could do anything but maintain the visual quality of daylight. It should be borne in mind that strictly speaking it is impracticable to maintain daylight conditions in the evening, since although the wave-length factors might be kept constant, the intensity and uniformity of the illumination would almost inevitably be reduced. Wave-length constitution is only one of the variables in the visual stimulus which affects the color quality of the sensation. Apparent color is also a function of intensity, both absolute and relative. It varies in a most remarkable manner, also, with changes in intensity, when the retina has been adapted to a specific color.

If the eye has been exposed for a fairly long time to a certain color, such as yellow, and then the level of illumination is lowered, the original field of exposure is smeared over with a thick layer of color complementary to that of the original—and still existing—stimulus; in our example, blue. I have studied this very interesting phenomenon in considerable detail, and have called it the *chromatic dimming effect*. The pertinancy of this effect to our present discussion lies in the fact that the coming of evening necessarily introduces a dimming in the general illumination, from 1,000 to about 0.1 millilamberts roughly; so that if, as Hering claims, daylight is actually yellowish, evening light although physically of the same quality, should appear bluish, as a result of the chromatic dimming effect.

The problems of color are very closely linked up with those of luminosity, and especially with the conceptions of "white" and "black." Physically, we define a "black body" as one which possesses non-selective absorption, and has an emission curve following a certain equation. The apparent color of this body, of course depends upon its temperature; it will only appear black when its temperature is low, and there will be only one tempera-

ture at which it will appear strictly white. Below this temperature it will be yellowish or reddish; above this temperature bluish.

There has been considerable discussion, in connection with colorimetric procedure, concerning the definition of "white light." It seems to me obvious that "white light" or "white" radiation can be defined logically only with reference to the properties or reactions of the normal human visual apparatus. White radiation is radiation which produces the sensation of white, or the achromatic visual quality, whether it be white or some shade of gray. The existence of complementary pairs of colors makes it evident that there must be an infinite number of different combinations of wave-lengths which will produce this sensation, and consequently it becomes desirable to add the further criterion that "white" radiation must have the distribution characteristic of a black body. The tendency to identify white light in this sense with solar radiation, or with black body radiation corresponding as nearly as possible with solar radiation, is based upon the hypothesis that sunlight actually produces the sensation of white. If Hering's assertion, already referred to, is correct this hypothesis cannot be retained.

It is remarkable that the distribution curve of solar radiation, plotted with respect to wave-length shows a maximum closely coinciding in position with that of the human visibility curve, and still more remarkable that the discrepancy between the positions of the two maxima is such that it can be explained by the cooling off of the sun since that evolutionary period in which the visibility curve was first established in the human species. If it is true, as Hering alleges, that sunlight is slightly yellowish, this fact can be explained by the same cooling off of the sun, on the supposition that coincidence of the maxima of the visibility and a black body radiation curve would normally yield a pure achromatic sensation. In other words, it seems reasonable to believe that color vision is a physiological device by means of which the organism detects a deviation of wave-length distributions from primitive solar distribution, which would be approximately the distribution of a black body at a definite temperature. Consequently it appears to be a commendable suggestion that "white light" be defined, for colorimetric purposes, as radiation having

a black body distribution, with its maximum coinciding with that of the cone visibility curve, *viz.*: 555 $\mu\mu$.

Hering's opinion that sunlight is not strictly white, is based more on the results of dimming effect experiments than on direct observation. It is of course recognized by everyone that the sun itself appears yellow, but this appearance can easily be explained as due to contrast with the vast expanse of sky blue in which the sun is always set. However, it is claimed by Hering that if the retina is adapted to sunlight, and the stimulus is then simply dimmed by the proper amount, the result is the production of a distinct blue. The physiological criterion for "white" would thus be that dimming should produce no apparent color, but merely gray. In my own experience I have found this to be a very sensitive test, but I have not as yet been able to apply it to radiation which I knew to have a black body distribution with its maximum at 555 $\mu\mu$.

SOME THEORETICAL COLOR PROBLEMS.

It may not be entirely without interest in a paper of this sort to refer to some of the more purely theoretical problems of color vision. In several respects color vision is one of the most mysterious processes of which nature affords us an example. Even when we lay to one side the fundamental mystery of the relation between consciousness and matter, there are a number of aspects of the process which have proven themselves singularly baffling.

The physical spectrum is qualitatively continuous from one end to the other, involving only a progressive change in wavelength. The visible or color spectrum, however, appears to be split up into regions which are qualitatively more or less distinct. This demarcation of colors in the spectrum as it appears to the eye is so definite that early physicists, such as Brewster, Wollaston, Goethe, *et al*, could not avoid the idea that there existed a number of distinct kinds of light, red, yellow, green, blue, violet, etc., which were mixed together in different parts of the spectrum in varying proportions. We now know that this relative discontinuity of the visible spectrum is due to the action of the retina or the visual apparatus as a whole, and not to the existence of qualitatively distinct kinds of radiation.

However, this is about as far as we have been able to go, with

any feeling of security. We have thus far failed to separate out well authenticated physiological or psychological color units, or to arrive at a clear idea of what the process is by means of which the retino-cerebral mechanism adjusts itself to changes in the wave-length constitution of the stimulus. We can hardly avoid the conviction that the immediate reaction of the retina is a photo-chemical process, and that more than one photo-chemical substance is involved. By color mixture and matching experiments we arrive at the conclusion that at least three such substances must exist, but we have not been able to prove that there are only three, nor have we been able to find any plausible explanation of the antagonistic or complementary relationships of certain pairs of wave-lengths. Theories have been advanced, of course, but they have all failed to achieve that close quantitative contact with experimental results which is demanded for verification.

In order that an animal should be able to make its color discriminations the basis of definite action, the results of these discriminations must be transmitted to the brain centers, and thither, to the motor nerves. Experiments seem to show that stimulation of a single retinal cone can give all of the elementary color experiences, so that it must be possible for the differentiae of all of the specific color reactions to be transmitted along a single nerve fiber. This contradicts the very general principle of "specific nerve energies," which supposes that the excitation of a single nerve can vary only quantitatively and not qualitatively. Although considerable doubt has been thrown upon this principle in recent years, no one has yet shown how qualitative differences can be transmitted along a nerve. Sufficient difficulty is being found in endeavoring to explain the manner in which quantitative variations are conducted from the sense organ to the brain.

The problem of identifying, or of selecting *primary colors* is of course closely bound up with the question of the actual mechanism of color vision. Much confusion exists in the discussion of primary colors, and in arguments in which primaries play a part, because of uncertainty or variability in the choice of criteria by which primaries are picked out. There are almost as many different sets of primaries as there are distinct theories of the color process. The Young-Helmholtz theory, as worked out experimentally by König and Dieterici, demands three primary colors,

an extreme spectral red (mixed with a slight amount of blue), a green ($505\ \mu\mu$), and a blue ($470\ \mu\mu$). The Hering theory, developed empirically by Westphal, demands an extreme spectral red (again mixed with a slight amount of blue), a yellow ($574.5\ \mu\mu$), a green ($505.5\ \mu\mu$) and a blue ($478.5\ \mu\mu$). The Hering theory also includes black and white as primary colors.

In order to avoid some of the confusion which now exists in the discussions which make use of concepts of primary colors, it would seem to me advisable to define a primary color in a broad way as *one of a small group of colors in terms of which any possible color can be expressed*. Primary colors should be distinguished carefully from *primary visual stimuli*, which might be defined as members of some small group of stimuli in terms of which any possible form of *retinal response* can be expressed. Colors are the qualities of our immediate experience; stimuli are the physical forces which act upon the retina.

If we accept this broad definition of a primary color, it is permissible to develop a number of different sets of primaries, each set capable of entering into formulae which will represent any conceivable color, and determined in its constitution by the conventions which have been adopted for its establishment and use. Thus, the *pigment primaries* are red, yellow and blue, and other colors can be expressed in terms of these by specifying the relative proportions of the primary pigments which are mixed together. The *radiational primaries* of the Young-Helmholtz scheme, on the other hand, must be combined into formulae representing proportions of radiation or of light; while the *psychological primaries* of Hering's system are the reference points of a subjective hue or quality scale. Corresponding with each set of primary colors there will be a set of primary stimuli, or *vice versa*. In the Young-Helmholtz scheme we determine the stimuli experimentally and deduce the colors; in the Hering system the reverse procedure is employed.

In a discussion of the psychology of color, the psychological primaries of the Hering theory should be given more than a passing notice. Physicists and engineers, generally, either are unaware of the existence of this set of primaries or else neglect it as being of no significance, a state of affairs which is not entirely justified. Hering's analysis starts with color itself, considered as

a phenomenon of immediate experience; radiant energy and wavelengths come only as a secondary consideration. He asks the question: "What colors are in our experience qualitatively simple, and what colors appear to be fusions?" He answers with Leonardi da Vinci, Goethe and others, that the simple and unique colors are red, yellow, green, blue, black and white, and that all other experienced visual qualities look like fusions of these qualities in various proportions. Although yellow can be produced by the mixture of red and green lights, it does not *look* like a mixture of red and green, any more than white *looks* like a mixture of red, green and blue.

Considerable time has been spent by psychologists in endeavoring to determine exactly what is meant by the criterion of *simplicity*, or purity, which is employed in the choice of the psychological primaries. The color orange is not a compound in the sense in which a pattern made up of red and yellow dots is a compound, for the sensation orange is just as homogeneous as is that of red. Some authorities, such as Von Kries, have asserted that this concept of simplicity can be given no definite meaning in its application to the color qualities, and hence that the psychological primaries should be abandoned. My own opinion is that in the selection of these primaries, as in other developments of human thought, concepts have been used which were only half-formed but which nevertheless rested upon real distinctions, and consequently are capable of being made clear-cut, although in this clearing-up process their complexion may be markedly altered. The exact meaning of the term "simplicity" can be developed mathematically from a study of the relations of the color qualities in the spectrum, but the subject is too difficult a one for consideration in the present paper.

I wish, however, to recommend to illuminating engineers who are interested in the problems of color, that they give some attention to the system of the chromatic qualities which Hering and his followers have developed. The purpose of "color in lighting" lies in the visual consciousness; Hering's analysis is based upon a direct study of the elements of this consciousness. The earliest students of color problems based their theories of light upon a subjective classification of the color sensations, and although we now know that, considering the objective factors the understand-

ing of which they had in view, their point of attack was ill-chosen, we can hardly doubt that the facts which attracted their attention are actually relevant to a comprehension of subjective and organic factors, which enter into the ultimate goal of illuminating engineering.

Another unsolved mystery of color vision is that of its evolutionary origin and its biological significance. To the layman it may seem absurd to ask "What is the use of color vision?" because there are so many practically important discriminations in our every-day life which depend upon, or at least are aided by a perception of color. However, the pertinency of the question increases when we consider, first, that nearly all of these practical situations have been created in the course of social development, because color vision already existed; and, second, that even in our complex colorific civilization the color-blind persons gets along with very little difficulty, so that he may never become aware of his defect until he is carefully tested in the laboratory.

Some reasons exist for believing that originally color vision was developed as an adjunct of the reproductive function, and should be considered virtually as a "secondary sexual character." Color blindness appears in heredity to be a "sex-linked character," as it occurs some forty times more frequently in the male than in the female. The females of many species are drab, for protection, while the males are highly colored. It is not improbable that this may have been the case with the fur-coated progenitors of the human species, and that color vision is in reality a vestige of by-gone evolutionary conditions, which has now been distorted from its primitive function, the recognition of a mate.

A more plausible view is possibly to be found in the consideration that, although practically every judgment which we make on the basis of color can be made also on a basis of luminosity or shape, color discrimination greatly increases the speed with which such judgments can be delivered. The visual discriminative reactions of the color-blind individual are often slow and hesitant. The function of vision is of such tremendous importance for the welfare of the individual that any feature in its working which could add appreciably to its general efficiency would markedly increase the chances of the individual or species in the struggle

for existence. Color perception, also, is more absolute than is the perception of luminosities. The tremendous changes in illumination to which the eye is forced to adapt itself make it practically impossible for the visual mechanism to evaluate luminosities save in relation to other, simultaneously presented, luminosities. On the other hand, although color adaptation occurs, its range is sufficiently small so that our color sense provides us readily with judgments of absolute as well as of relative color.

COLOR AND MENTAL EFFICIENCY.

My feeling, to which I have already alluded, that the topic "The Psychology of Color," exhausted the contents of the science of color was somewhat allayed when the committee informed me, in answer to an inquiry concerning their conception of the scope of my paper, that what was desired was a discussion of "the affective value of color." My instinctive reaction to this problem was that nothing was known about it, and that probably there was nothing in it to be found out.

However, it is my good fortune to have at hand an account of the recent investigations of Dr. S. L. Pressey, in the Harvard Laboratory, on "The Influence of Color Upon Mental and Motor Efficiency." Dr. Pressey's work, although of necessity limited in its scope, represents—so far as I am aware—the only systematic attempt which has thus far been made to study the relations of color to the higher psychological processes, under well-controlled laboratory conditions. In considering this subject, I shall therefore confine myself to a brief summary of his methods and results.

The problem of the *higher psychology of color* may be subdivided into the problems of color preference, and of the influence of color on mental efficiency. Both of these factors may be supposed to involve the influence of affective tone, *i. e.*, the pleasantness or unpleasantness of the color experience; or the emotional effect. The literature of these topics is fairly extensive, but it is characterized throughout by lack of scientific method and lack of agreement. Practically every color has been preferred by one group of individuals or another, in one historic period or another. All of the colors have been employed as symbols of happiness, and all as tokens of death. Statistically, the literature makes no state-

ments; one color appears to be almost as good as another for any purpose, except that of actually copying the aspects of nature. There is some agreement that brightness and redness have a "stimulating effect," but even this is very indefinite.

Dr. Pressey's results confirm this conception of the effective neutrality and equivalence of the colors, considered as isolated factors of experience. He made no attempt to deal with color patterns or sequences, such as enter into the chromatic fine arts, but simply studied the effect upon mental performance of single colors spread uniformly over the visual environment of the subject. The colors employed in the principal series of experiments were primary red, green and blue, of about equal saturation. The subjects sat before a table which was covered with a white, unglazed paper, and this was flooded with the colored light from above, the eyes being protected from direct glare. Large gelatine filters were employed, and the brightness of the table top was in all cases about 7 candles per square meter. Pre-exposure of the eyes was given to a "normal" tungsten light, for which the colored light was substituted (without dark interval) during the test period. The exposure periods were timed systematically.

As indices of the possible mental effects of the colors, Dr. Pressey made use of the subjects' performance in a number of fundamental "mental tests," and also measured pulse and breathing rates. Previous work by Stefanescu-Guanga, at Leipsig, had indicated a marked influence of color upon respiration and heart action, but Dr. Pressey's carefully taken records show absolutely no consistent effects of this sort. Nine subjects were tested, over a period of 10 to 12 weeks.

In order to test the effect of the colored light upon general muscular facility, the subjects were required to tap at a comfortable rate with the finger during one-minute periods. The five subjects employed showed no influence due to color, although significant increases in the tapping rate were obtained by increasing the *brightness* of the light, proving the test to be sensitive to the general sort of effect which was being studied. Another test of a similar nature, sensitive to changes in general neuro-muscular tone, consisted in requiring the subject to register a definite pressure with the hand upon a postal scale. The results again were negative, both for color and for brightness.

Closer contact with the immediate affective experience of the subject was obtained in a series of experiments made upon the effects of color upon the pleasantness of "touch substances." These touch substances were simply small squares of materials varying in texture. The subject passed his finger tip over them in succession, while exposed to the action of the colored light, and estimated the pleasantness or unpleasantness on a subjective scale of seven "points." Twenty substances were used, but no influence of the color upon the judgments was evident.

A further test, clearly involving mental efficiency, was that of the rate of multiplying under the colored illumination. Great care was taken to allow for practice effects in this work, and although increased brightness increased the rate of work, no specific effect due to color could be detected.

The next test to be tried was that of the so-called "free association experiment." The procedure of this experiment is simply for the experimenter to speak a single word, and for the subject to reply as quickly as possible with the first other word which comes to his mind through association. The time required for him to "think" of this latter word is taken with a stop-watch. The recall of ideas by association is of course one of the most fundamental principles of mental action. Eight subjects were tested over a long period, but no influence either of color or brightness was found. Similarly negative results were obtained with respect to the rate at which the subjects memorized nonsense syllables.

The final test employed by Dr. Pressey in his experiments is what he calls a "continuous choice reaction." In the ordinary choice reaction experiment the subject is required to react in one way if a certain stimulus is presented, but in a different way if a certain other stimulus is presented. In other words his muscular response is specific with reference to the stimulus. In Dr. Pressey's continuous choice reaction, as soon as the subject has completed one reaction he is automatically presented with another stimulus, to which he must react immediately, and so on indefinitely. The number of correct reactions which he can make in a specified time determines his score in the test. This test presents in elementary form the typical situation which we face in all neuro-muscular or mental adjustments, but no appreciable in-

fluence of color upon the average performance of six subjects, could be detected; although brightness had a slight effect.

During the experiments, Dr. Pressey often required his subjects to make introspective reports concerning the affective value of the colors, as directly experienced. These reports not only showed very little consistency from individual to individual, but also varied from day to day in the same individual. Red was more often found to be exciting than indifferent, and bright illumination was usually preferred to dim, but in certain subjects the reverse was true.

Dr. Pressey, himself, would not claim that his experiments dispose entirely of the proposition that the use of color in lighting may have a practical influence upon human happiness or efficiency. The tests employed, although representative of fundamental psychological functions, were not exhaustive. It would be desirable to supplement laboratory investigations of this sort by experiments carried out with actual factory operatives working in their usual environment. However, it seems to me that Dr. Pressey's work, being carried out with twenty-six subjects, over a period of three years, does establish a strong presumption that the higher psychological influence of color in illumination—if it exists—is of very minor importance.

Dr. Pressey's tests were designedly selected so that their results would not depend upon any direct ocular factors, such as for example, visual acuity. Owing to the chromatic aberration of the eye, monochromatic light gives a better defined retinal image than does white light. Moreover, Nutting has shown that the eye is quite accurately corrected for achromatism in the mid-region of the spectrum—the region of high visibility—but very poorly corrected in the end regions. Consequently, since in practical lighting we are forced to employ a wide spectral range, the acuity factor would seem to demand the use of yellow green. Considerations of luminous efficiency also obviously make the same demand.

It should be borne in mind that generalizations concerning the psychological effects of color may fail to apply to individual cases. The generalizations are simply averages, in which a multitude of individual differences cancel one another out. The affective values of specific colors in individual minds will depend upon the idio-

syncrasies of individual experience. Psychopathic cases are not rare in which the sight of a certain color suffices to induce an hysterical fit or to arouse an emotion of terror which quite paralyzes the mind. Such phenomena, however, are due to associations of ideas based upon past emotional experience, and may occur in connection with stimuli of any sort. Uniformities in the social environment of all human beings may produce some uniformity in these associations, such as that of red with danger—blood, fire, and railway signals—but actually these uniformities do not appear to be very marked.

CONCLUSION.

Even if the utilization of a homogeneous spread of color in illumination should not recommend itself upon rigidly practical grounds, this would not mean that the illuminating engineer should lose his interest in color. The affective value of color lies essentially in *color combinations*, and the production of color combinations which are pleasing to the eye, although primarily a task for the artist, cannot always be accomplished without the aid of the illuminating engineer. Great credit is due to Mr. Luckiesh for his clear recognition of the fact that the ultimate effect produced by a painting or a piece of sculpture depends almost as much upon the manner in which it is lighted as upon the technique and ideals of the artist.

Although the principal dimension in which we combine colors to form color patterns, is that of space, those who are interested in "color music" believe that they can also be combined in a temporal sequence, with pleasing effects. Although it seems doubtful if color sequences can ever possess the affective values which characterize the tone sequences of phonic music, the illuminating engineer should lend his assistance to this new artistic enterprise, as to the world of artistic endeavor in general.

It is very important to recognize that "affective values" are by nature unstable, and difficult to attach to definite forms of stimulation. The law of affective adaptation tends to reduce the pleasantness or unpleasantness of any stimulus to a neutral level, with repetition or continuation. Only those stimuli which arouse fundamental instinctive tendencies, such as those of sex, hunger and fear, can be relied upon to yield anything approaching re-

liable affective results. Dr. Pressey found that this principle of affective adaptation was much in evidence in the introspective reports of his subjects.

On the other hand, the law of adaptation itself implies another principle, which is of great practical importance in the control of the affective life. This is the principle of *novelty*. Outside of the major instinctive emotions, and also to a marked extent within them, most of the pleasures of life are referable to novelty, to the achievement of new experiences. The old scenes and the old melodies pall upon us with repetition, and we look for new. We travel in order to get a change; we stage a new drama; we may even declare war in order to relieve the monotony.

What a remarkable medium for the production of novelty we possess in color, with its infinitude of tones, saturations, shades and contrasts! It may not be the function of illuminating engineering to light our streets with green in order to inhibit robbers and gun-men, or to flood our dining rooms with red to stimulate digestion. On the other hand, to provide us with an infinite variety of colors, which we can choose according to the passing fancy of the hour, may be a real service not only for the pleasure of the instant, but indirectly for our mental and moral efficiency, as it is governed by our satisfaction in living.

PART V.

THE WORK OF THE NATIONAL BUREAU OF STANDARDS ON THE ESTABLISHMENT OF COLOR STANDARDS AND METHODS OF COLOR SPECIFICATION.*

BY IRWIN G. PRIEST.

PURPOSE OF THIS PAPER.

The purpose of this paper is to present to the Illuminating Engineering Society an outline of the color standardization work being undertaken at the Bureau of Standards. It is hoped that it may lead to a closer co-operation between the Society and the Bureau in whatever attempts they may make to place the matter of color standards and color specifications on a more satisfactory and reliable basis.

THE DEMAND FOR COLOR STANDARDIZATION.

It is difficult for one not in close touch with the subject to realize the extent and urgency of the demand made by industrial and commercial as well as scientific interests for the standardization and specification of colors. For several years the Bureau of Standards has been receiving numerous requests for information, advice and assistance in this matter from the most diverse sources. Among these applicants there are represented:—railway officials, refiners of oils, paint and varnish manufacturers, tobaccoists, manufacturers of chocolate, dairymen, physiologists, psychologists, illuminating engineers, dealers in dyes, lithographers, packing companies, teachers of art, paper manufacturers, textile manufacturers, chemists, manufacturers of optical apparatus, glass manufacturers, ophthalmologists, state governments and the following departments and bureaus of the national government: Bureau of Chemistry, Navy Department, War Department, Government Printing Office, Post Office Department, Bureau of Engraving & Printing, Bureau of the Census, Bureau of Entomology, Bureau of Lighthouses, and the Interstate Commerce Commission.

* Written by the Associate Physicist in charge of color standardization and published with the approval of the Director, National Bureau of Standards, Washington, D. C.

Formal tests of the color, spectral transmission, and transparency of materials have been made and reported to the following applicants: State of Minnesota, Navy Department, Post Office Department, United States Customs Service, Bureau of Entomology, Johns Hopkins University, Interstate Commerce Commission, Geological Survey, Weather Bureau, Pennsylvania Railroad Company, Swift & Company, Leeds & Northrup, Warren Manufacturing Company, Westfield River Paper Company, Keuffel & Esser, New York Blue Print Paper Company, Automobile Club of America, National Tracing Cloth Company, Corning Glass Works, Rosenthal Electrical Laboratory, T. A. Wilson Company, Pennsylvania Wire Glass Company, A. T. Thomas Company, National Dairy Union, and others among whom are represented chemists, illuminating engineers and refiners of oils.

Tests are now pending for the following: Bureau of Medicine & Surgery (Navy Department), United States Public Health Service, American Writing Paper Company, and Dr. Nelson M. Black, ophthalmologist.

Owing to the impossibility of handling them within a reasonable time, it is occasionally necessary to decline to make requested tests, especially when it appears to us that the results would be of little interest or value or we are aware that the test can be made by some commercial laboratory to whom we refer the applicant.

The correspondence of the Bureau presents very cogent evidence of the need of color standards and color specifications. To enable the Bureau to meet the demands mentioned above, Congress made a special appropriation for the fiscal year 1917 and has continued it for 1918. With this fund an investigation of the subject of Color Standards and Methods of Color Measurements and Specification has been undertaken and is now in progress. Some account of it will be given in the following paragraphs.

THE PRESENT STATUS OF COLOR STANDARDS AND COLOR SPECIFICATIONS.

While the fundamental principles of the subject are fairly well understood by a few experts who have given particular attention to it, the practice of color specification is in a very un-

satisfactory and indeed chaotic state. This condition is due to the following circumstances:

1. Lack of agreement as to standards, definitions, nomenclature and methods, even among those experts who are competent to deal with the subject.
2. The failure of those most vitally interested in the subject from a practical and commercial point of view to comprehend at all the fundamental principles involved, *i. e.*, a lack of clear concepts by those most interested.
3. The widespread current use, without standardization, of pseudo standards, and empiric methods having no definition or even description other than their maker's or originator's name.
4. The lack of reliable quantitative data on the fundamental physical, physiological and psychological constants and factors involved.
5. The lack of well made precision instruments suitable to make the measurements requisite for color specifications.

Proposals for remedying these conditions will be made in the present paper.

OUTLINE OF WORK IN PROGRESS AND PLANNED AT THE BUREAU OF STANDARDS.

The work contemplated at the Bureau of Standards is limited to that having direct bearing on measurements and methods of specification. It is thus largely physical. While certain physiological factors must be considered, we do not expect to deal with the large field of subjective or psychological phenomena, although they have great interest.

The work which the Bureau can do and has already begun can be considered under two main headings and several sub-headings as follows:

I. EXPERIMENTAL WORK.

- A. *Development of Instruments and Methods for General Fundamental Work.*
- B. *Determination of Fundamental Data and Establishment of Working Standards.*
- C. *Application of Spectrophotometric and Colorimetric Methods to Specific Technical Purposes.*
- D. *Routine Tests.*

2. ORGANIZING AND EDUCATIONAL WORK.

- A. *Co-operation and Discussion with Experts Outside the Bureau for the Purpose of Developing and Establishing Uniform Nomenclature and Standards.*
- B. *Compilation and Co-ordination of Previous Data. Preparation of Tables, Graphs, etc.*
- C. *The Giving of Information by Correspondence, Conference and Circulars.*

The following paragraphs will explain more fully the activities just outlined:

I. EXPERIMENTAL WORK.

A. *Development of Instruments and Methods.*—As pointed out above, the lack of suitably designed and well-constructed instruments as well as the lack of established and recognized methods is a serious impediment to significant color specifications. (Instruments and methods must perforce be considered together.) It is not only necessary that instruments and methods be apparently suitable as judged by casual examination. After methods are formulated and instruments constructed, a vast amount of testing and counterchecking must be carried out to verify the validity of results and give confidence in them. The Bureau is undertaking this work in a thorough-going, painstaking way in the hope of eventually overcoming the uncertainty and confusion that has been introduced by the commercial use of methods and instruments having no secure foundation. The attention given to the development and testing of fundamental methods and instruments is noted under the following sections (a) and (b).

(a) The improvement, counterchecking and standardization of spectrophotometric determinations: Of whatever value so-called "colorimeters" may be in special cases, it must be admitted that *the fundamental basis of color specification is spectrophotometry*. "A spectrophotometric table, derived from at least 25 points (for a continuous spectrum), gives the only unique description of a color, and it appears probable to the writer that the requirements of precision technical color measurement are most likely to be met by the development of simple and rapid means of plotting and recording accurate spectrum plots of reflection or transmission characteristics."²

² H. E. Ives, *Jour. Franklin Inst.*, Dec., 1915, p. 700.

For a number of years the most of our routine spectrophotometric work has been done on a König-Martens spectrophotometer. By the use of specially designed record forms and slide-rules, its use has been greatly simplified, and rendered convenient and rapid.

Considerable checking of the reproducibility and accuracy of results has been done and is in progress. During the past year, test specimens of various colors of glass have been carefully prepared and measured on the König-Martens instrument at the Bureau. Through the courtesy of the Physics Department of Cornell University, these same specimens have been again measured by K. S. Gibson of the Bureau of Standards on the Lummer-Brodhun spectrophotometer at Cornell and their transmissions for blue, violet and ultra-violet also determined by a photographic method (Hilger sector apparatus). This procedure makes possible the detection of small errors and gives much more confidence in final results. Such counter-checking of results will be continued and elaborated, and reports published later.

Apparatus is being installed for spectrophotometry by another independent method using the photo-electric effect.

(b) Design, construction and testing of the practical utility of "colorimeters" including the monochromatic, trichromatic and rotatory dispersion types: Notwithstanding their obvious shortcomings, a thorough-going investigation of the above types of instruments is of great interest for the purpose of determining their practical utility for certain purposes.

A monochromatic colorimeter was designed at the Bureau by P. G. Nutting in 1911.³ An improved model of this was later made by Hilger after Nutting's designs and the Bureau has recently obtained one of these instruments which will be studied in regard to reproducibility of results and applicability to practical problems. Another type of monochromatic colorimeter after a design by Priest,⁴ has been partly constructed in the Bureau instrument shop.

In 1908 the Bureau made very extensive tests of the Ives trichromatic colorimeter,⁵ but found the results lacking in the

³ Bureau of Standards Sci. Paper 187.

⁴ *Jour. Wash. Acad. of Sci.*, Vol. VI, Feb. 4, 1916, p. 74.

⁵ F. E. Ives, *Jour. Franklin Inst.*, 164, 1907, p. 421.

reproducibility and accuracy requisite for precision technical specifications. This probably is partly due to the essential limitations of the method as pointed out by H. E. Ives,⁶ and to a lack of a standardized illumination and method of use; but the erratic results are also partly due to the faulty mechanical design and construction of the instrument. A trichromatic color-screen instrument of mechanical and optical design radically different from the Ives instrument is now being built at the Bureau. It is hoped with this instrument to test thoroughly the possibilities of the trichromatic screen method.

The Bureau has made rather extensive tests of the Arons Rotatory Dispersion Chromoscope⁷ and apparatus on the same principle made in the Bureau shop. The essential feature of this instrument is that the color being tested is color-matched by light passing through a quartz plate between nicol prisms. By changing the thickness of quartz and rotating one of the prisms the color can be adjusted. With two such quartz-nicol systems in series, Arons found that any color could be matched; and it is possible to compute, from the instrument readings, the spectral transmission of the system.⁸ Data upon the reproducibility and precision of readings with this instrument and on the personal equation have been reported to the Society of Cotton Products Analysts.⁹

B. Determination of Fundamental Data and Establishment of Working Standards.—The fundamental data required in colorimetry fall in two classes, *viz*:

(a) Physical data, such as the relative spectral distribution of power in various light sources, and the spectral transmission and reflection of various materials.

(b) Physiological data such as the visibility of radiation and the sensibilities to hue, brightness and purity differences.

(a) Physical data: Data on the spectral distribution of a standard reproducible source have already been obtained at the Bureau by Coblentz¹⁰ independent of their interest in the present

⁶ *Jour. Franklin Inst.*, Dec., 1915, pp. 699-700.

⁷ *Ann. der Phys.* (4), Vol. 39, 1912, p. 545.

⁸ Priest, *Phys. Rev.* (2), Vol. 10, 1917, p. 208.

⁹ Priest, *Proc. Soc. of Cotton Products Analysts*, Fifth Annual Convention, 1914, p. 24. (There are several serious misprints.)

¹⁰ Bureau of Standards Bull. 13, p. 363.

case. Our working standards are referred to this by direct color-matching, spectrophotometric determination, or color-matching by the rotatory dispersion method.¹¹

Although considerable data on the color of "average daylight" may be found in the literature, we propose to obtain more data on this by the spectrophotometric and rotatory dispersion methods on which to base a definition for a standard artificial daylight.

There are on the market several combinations of lamps and colored glasses intended to give "artificial daylight." These have been developed by different experts on the basis of somewhat different definitions of "daylight." It is important that these be intercompared and that a standard "artificial daylight" be adopted. An investigation of these "artificial daylights" is now in progress at the Bureau.

An original method of producing "artificial daylight" has also been devised at the Bureau and developed theoretically and experimentally. It has been found by theoretical computation that the spectral distribution of daylight can be approximately matched by light from an artificial source modified by transmission through a quartz plate between nicol prisms. The constants for such apparatus have been determined theoretically, and the color-match verified experimentally. A paper on this subject is in preparation for publication.

Various colored salts and other substances in solution have some value as working standards of color. It is important that substances used for this purpose have their spectral transmissions accurately determined. During the past year the spectral transmissions of a number of such solutions proposed as color standards by Professor H. V. Arny and submitted by him have been determined. A few other solutions have been examined and it is planned to extend this investigation to include as many as possible reproducible colored solutions of known purity and concentration. While there exist considerable previous data on this subject, they are largely qualitative or only crudely quantitative. The purpose of the present investigation is to obtain quantitative data of the highest possible accuracy.

Colored glasses have been considerably used as standards in color specifications. Notable among these are the Lovibond

¹¹ Priest, *Phy. Rev.* (2), Vol. 10, pp. 208-212.

glasses. At the request of the Society of Cotton Products Analysts, the Bureau in 1913 made an investigation of the uniformity of these glasses, which disclosed considerable discrepancies.¹²

Colored glasses are, however, important as working standards of color. An extensive collection of colored glasses of standard manufacture is being made. The specimens are carefully prepared, marked, and filed in a systematic way. Their spectral transmissions are also being carefully determined by different methods and filed so as to be available for ready reference. It is intended to continually extend and augment this collection of glasses and data.

(b) Physiological data: Data on the visibility of radiation by König, Ives, Nutting and Coblentz are already available.¹³

Data on sensibility to hue difference have been obtained by many investigators,¹⁴ but more data are needed to establish the curve of the average eye. We hope to contribute some of this, referring as far as possible to the same subjects for which the visibility has been determined by Coblentz. It is also planned to correlate such data with the results of practical methods of color blindness diagnosis.

Few data are available on sensibility to purity differences and while no work on this has been begun here, it is realized that the want must eventually be satisfied.

The sensibility to brightness differences is fairly well known¹⁵ but it will probably be desirable to redetermine this by the method of mean errors as recommended by Nutting.¹⁶

C. Application of Spectrophotometric and Colorimetric Methods to Specific Technical Problems.—The end and purpose of the Color Standards Investigation is to provide standard methods and

¹² Priest, *Proc. Soc. Cotton Products Analysts*, 4th Annual Convention, 1913, p. 6.

¹³ *Phil Mag.*, Dec., 1912, p. 853.

TRANS. I. E. S., Vol. 9, 1914, p. 633.

Phy. Rev. (2), Vol. 9, p. 88, and Bureau of Standards Sci. Paper 303.

¹⁴ Mandelstamm, *Graefe's Archiv.*, Vol. 13, Abt. 1, p. 399.

Dolrowlsky, *Graefe's Archiv.*, Vol. 18, Abt. 1, p. 66.

Peirce, *Am. Jour. of Sci.*, Vol. 126, p. 301.

König and Dieterici, *Wied. Ann.*, Vol. 22, p. 579.

König, *Verh. der Physiol. Ges.*, Berlin, 1885-6, No. 17.

Uhtoff, *Graefe's Archiv.*, Vol. 34, Abt. 4, p. 1.

Steindler, *Wien. Sitz.*, Vol. 115, 2A, p. 39.

Jones, *Jour. Franklin Inst.*, Vol. 183, p. 500.

¹⁵ König and Brodhun, *Sitz. A. W.*, Berlin, July 26, 1888.

¹⁶ *Outlines of Applied Optics*, p. 124.

apparatus needed to make color specifications possible in science, industry and trade. It would be useless to enumerate the applications that may be required or contemplated; but it is thought that brief mention of those that have been dealt with or are now pending may be of interest.

(a) Specification of the saturation of yellow tints in butter and oleomargarine: Frequent and persistent demands have been made on the Bureau to draft a form of specification which would be suitable to define rigorously in law a limiting value of what, in common parlance, may be called the "color," the "depth of color" the "strength of color" or the "yellowness" of butter and oleomargarine. In response to this demand, methods have been developed and definitely formulated; and a report on this subject has been published.¹⁷

(b) The photometry of lights of different colors and the specification of their colors: The determination of the relative candlepowers of lights of different colors is one of the most difficult problems of photometry, while the convenient specification of the color of a light is the fundamental problem of color specification. The rotatory dispersion method which greatly facilitates the solution of both of these problems has been developed and tested.¹⁸

(c) Examination of glasses intended to protect the eye from harmful radiation: There are on the market a number of glasses recommended to protect the eyes. At the request of the American Medical Association, we have undertaken to determine, incident to the Color Standards Investigation, the spectral transmissions of a considerable number of these glasses in the visible and ultra-violet.¹⁹ A great deal of this work has been done and a report will probably be published during the coming year.

(d) Color grading of cottonseed oil: Cottonseed oil is commercially graded by its color. At the request of the Society of Cotton Products Analysts, the Bureau has co-operated with them in investigating their standards, determining the spectral trans-

¹⁷ Priest and Peters, Bureau of Standards Tech. Paper No. 92.

¹⁸ Priest, *Phy. Rev.* (2), Vol. 6, p. 64.

Phy. Rev. (2), Vol. 9, p. 341 (for erratum see p. 580).

Phy. Rev. (2), Vol. 10, p. 208.

¹⁹ Some infra-red transmissions of such glasses have already been published. Coblentz, Bureau of Standards Tech. Paper No. 93.

mission of numerous oil samples and testing methods of color-grading. Several reports have been made but the investigation is still continued.

(e) Transparency of paper and tracing cloth: To meet the demands of purchasers and manufacturers, a standard method for grading the transparency of paper and tracing cloth has been formulated and published.²⁰

D. *Tests*.—As mentioned in the introduction to this paper, considerable time is given to spectrophotometric and colorimetric tests. While the Bureau will attempt, so far as time permits, to be of service in making important tests of this nature which can not be satisfactorily done by commercial laboratories, the general policy will be not to undertake tests that can be satisfactorily done elsewhere.

2. ORGANIZING AND EDUCATIONAL WORK.

A. *Cooperation and Discussion with Outside Experts*.—As pointed out above, the lack of established uniform nomenclature and recognized standards is a serious impediment to color specifications. Before attempting to inform and educate the non-expert, it is necessary that some conventions be agreed upon by the experts who have given special attention to this subject. An important feature of the work planned by the Bureau is the bringing about of such agreement. Probably the most direct and effective way to take this up is through the Illuminating Engineering Society. Several months ago²¹ the author pointed out the desirability of the Society having a Committee on Color. The Council, however, thought best to postpone action on this until after the present convention.

Such a committee could be of service by proceeding at once to formulate (in consultation with the Committee on Nomenclature and Standards) definitions for such terms as "white-light," "daylight," hue, purity, brightness, saturation, etc., and selecting definite unique terms to name the three color coordinates and their physical correlatives. The author has made some survey of the literature to determine the best usage of such terms and would be pleased to have certain proposals considered by such a

²⁰ Bureau of Standards Circular No. 63.

²¹ Letter of January 10, 1917, to the President, I. E. S.

committee before establishing usage in Bureau Circulars and other publications.²²

B. Compilation and Coordination of Previous Data. Preparation of Tables, Graphs, etc.—The introduction of uniform standards and methods presupposes the consideration and coordination of data from various sources. We are undertaking this task of compilation and coordination. Various data on the spectral distribution of sources, the visibility of radiation, hue-sensibility, and proposed “artificial daylights” have been collected and plotted to a uniform scale so as to be directly and immediately comparable. Usages of color names and terms by various authorities have been tabulated. The theoretical spectral distribution of a perfect radiator at many different temperatures as given by the formulas of Wien and Planck have been computed and plotted using most recent data for the constants. Such data will later find their place in a Bureau Circular. In the meantime they can be supplied individually to anyone having especial interest in them.

Colorimeters of the rotatory dispersion type have much to recommend them in the way of convenience and simplicity of observation; but the interpretation of the results in terms of spectral distribution or color theory is very tedious and complex. We expect to simplify this matter by the preparation of permanent reference tables and curves; and much of the computation for this purpose has been completed during the past year. About 600 curves giving the spectral transmission for various thicknesses of quartz and various angles between the principal planes of the nicols have been computed and plotted.

Complete tables to facilitate the determination of candlepowers of lights of different colors by the rotatory dispersion method as proposed by Priest have been prepared and published.²³

In some photometric and colorimetric work, the computations require frequent use of the square of the sine of an observed angle read in degrees and hundredths of a degree. There being

²² The author is now preparing a paper on “A Proposed Basic Nomenclature for Use in Colorimetry.” It was not possible to include this matter in the present paper; but the forthcoming paper may be considered as supplementing and extending the present one.

²³ McNicholas, Filgate and Cole, *Phy. Rev.* (2), Vol. 10, p. 213.

no tables of this kind of sufficient accuracy available, a set has been computed as follows:

- 0° to 10° at intervals of 0.02° to six decimal places.
- 10° to 80° at intervals of 0.02° to four decimal places.
- 80° to 90° at intervals of 0.1° to four decimal places.

The computation and copying of these tables have been carefully checked and photographic copies made for current use in the laboratory. They will possibly be published later. In the meantime a limited number of photographic copies may be supplied to those in need of such tables.

Less extensive tables of the fourth power of the sine and the square of the tangent have also been prepared.

C. *The Giving of Information.*—The demand on the Bureau for information and advice has been noted above. A great deal of time is spent in attending to such correspondence. As soon as the subject is sufficiently developed a circular will be published containing information covering many such inquiries. However, the time is not yet ripe for such a circular. It is very desirable that a more general agreement on standards, nomenclature and methods be obtained before its preparation. As stated above, the Bureau would appreciate the co-operation of the Illuminating Engineering Society in bringing about such an agreement.

PART VI.

SOME EXPERIMENTS ON THE EYE WITH DIFFERENT ILLUMINANTS—PART I.

BY C. E. FERREE AND G. RAND.

Synopsis: In previous papers a study has been made of the effect on the eye of differences in the way in which the light is delivered to it from a given type of illuminant. In the work of the present papers, I and II, a series of tests is begun on the effect of the illuminant itself. Eleven of the more common illuminants are used with the same conditions of installation, shading, etc., and a correlation is made between the lighting effects obtained and the power to sustain clear and comfortable seeing.

INTRODUCTION.

The belief seems to prevail among laymen and not a few technical and medical men that the kerosene flame as a source of light possesses advantages for the eye not had by other illuminants, more particularly the incandescent solids. At one of the earlier meetings of the American Medical Association's Sub-committee on the Hygiene of the Eye, the belief was expressed and quite favorably received that of all of the common illuminants the kerosene flame gives the best light for the eye and that it should be taken as our model for hygienic lighting. In the TRANSACTIONS of 1913, an eminent ophthalmologist writes: "It has been shown by experiment that the light which gives the maximum of illumination with the minimum of irritation to the eye is composed of the yellowish rays of the middle of the spectrum. For this reason the old fashioned candle and kerosene lamp have never gone entirely out of fashion." In a more recent article in the TRANSACTIONS (1915, Vol. X, pp. 1027-1033) we find a section on "Simulating Old Illuminants," and in the last paper read before the Philadelphia section of the Society a growing sentiment for the older illuminants was noted.¹ Leaving out of consideration the many things that have been said in popular and semi-technical publications on the effect of the eye of the

¹ See also *Electrical Review and Western Electrician*, July 24, 1915, p. 161.

color value of light, of which subject we do not wish to make a special point prior to experimentation, these are only a few of the more familiar statements of opinion that may be cited in evidence that there is a need for testing the effect on the eye of the light of the older illuminants (more especially the kerosene flame) as compared with the more modern illuminants, with the intensity, conditions of shading, installation and use, etc., the same in each case.

Two divisions may be made of this comparison: (*a*) with the illuminants compared used for the purpose of general illumination, and (*b*) with these illuminants adapted to local, reading table, or desk lighting. In the first of these cases differences in result would perhaps be more apt to occur because of the greater number and complexity of the factors present and the greater difference in difficulty in protecting the eye from unfavorable conditions relating to a set of factors which we have hitherto called the distribution factors. It is quite probable also that a comparative rating of illuminants made on the basis of local lighting in which case it is not difficult, for example, to eliminate high brilliancies from the field of view, will not hold for general lighting in which case the chief difficulty seems to be to protect the eye from high brilliancies. Because, however, of the greater difficulty in getting comparable installations for general lighting we have chosen to make the first series of tests with local lighting given by a single unit, a one-burner student lamp of the standard type with modifications suitable for the different illuminants employed. We have been led to choose this particular type of unit in part because the belief in the superiority of the kerosene flame for the eye is in the minds of those we have questioned associated largely with the lighting effects given by the student lamp; and in part because this lamp is well adapted to the control of conditions under which we wish the first series of tests to be made.

CONDITIONS TESTED.

Two series of experiments were conducted. In the first series the illuminants tested were a kerosene flame; a 50-watt, clear, metallized filament (Gem) carbon lamp; a 15-watt "mazda, type

B"* tungsten lamp (round bulb); a 60-watt "mazda, type B"* lamp; a 75-watt "mazda, type C"* lamp, and a 75 watt "mazda, type C2"* lamp. The kerosene flame (Lusterlite kerosene) was burned at a height of 3 in. (7.6 cm.) and had a horizontal candlepower of 15.8. For the sake of comparison with the kerosene flame it might have been desirable to have conducted the tests with the other illuminants equal to it photometrically, or approximately so, as well as with an equally illuminated reading page and test object. This was, of course, impracticable in case of the "mazda, type C"* lamps. For this reason two "mazda, type B"* lamps were used—one as nearly as possible equal in candlepower to the kerosene flame, the other to the two "type C" lamps. In choosing the sources care was taken also to have them all as nearly as possible of the same size or to have a check condition on this factor analogous to that described above; and to adjust the position of the lamp so as to sustain approximately the same relation to the shade. The bottom of the shade was, for example, in each case 2.5 cm. below the center of the luminous source. The lamp was placed behind and to the left of the observer in the position that was judged by several observers to give the most favorable conditions for reading. This position may be roughly specified as follows. The angle with the median plane of the observer made by a plane passing vertically through the center of the unit was approximately 21° ; and the line in the latter plane connecting the bottom of the shade with the center of the reading page formed an angle of approximately 38.5° with the horizontal plane passing through the center of the reading page. The reading page was supported by a rack fastened to the upright to which was attached the mouth-board used by the observer in taking the 3-minute record before and after work. This rack was inclined at an angle of approximately 30° with the vertical. To insure that the same amount of light fell on the reading page in each case, the brightness of the page was measured before and after work by means of a Sharp-Millar illuminometer with the test plate removed and calibrated to give readings directly in candlepower per square inch. The changes needed to give equality of illumination on the

* Trade Definitions: Gas-filled, *daylight* (blue) glass incandescent lamp—Mazda C-2.
 Gas-filled, clear glass incandescent lamp—Mazda C.
 Vacuum, clear glass incandescent lamp—Mazda B.

reading page were made by changing the distance of the lamp from the page. These changes in case of the first three illuminants were very small. For the remainder owing to the greater difference in the candlepower of the lights used, the equalization required that a greater difference in the distance of the lamp from the reading page be employed. This meant a slightly greater difference in the amount of general illumination given and a slightly greater difference in the brightness of the surroundings. That is, the lamps of higher candlepower placed at a greater distance from the reading page illuminated a larger field than the lamps of lower candlepower. In making these changes of distance care was taken to keep the angle at which the light fell on the page in all cases the same. Some difficulty was given also by the difference in the length of the lamps employed. For example, the long stems of the "type C" lamps made it necessary that the shade be raised if the filaments were to have approximately the same position in the shade as were had by the kerosene flame and the filaments of the shorter lamps. To take care of the needed adjustment in the height of the shade an extension shade holder was used.

Owing to the angle of direction of the light and the distance of the lamp, the test object had to be illuminated from a separate source. For this a "mazda, type B" lamp and an Ivanhoe-Regent steel reflector of the intensive type, aluminum lined, were used, placed in front and to one side of the test object at the distance and angle needed to give the required illumination. In order that the test object alone should be illuminated and not the surrounding wall, objects, etc., the opening of the reflector was covered and an oblong aperture was cut of the size and shape needed to give the cross section of light desired. The position of this aperture in the opening of the reflector was chosen with reference to giving the most even illumination of the test object. That is, the light was not taken directly from the lamp but from the most favorable part of the inner surface of the reflector. The test object was made to match the reading page both in brightness and color value. The match in color value was secured by means of thin gelatine filters covering all or a part of the aperture. If only a part of the aperture was covered, the filter was used as a diaphragm with an opening similar in shape

to the original aperture. There was, for example, enough difference in the color value of the illuminants that without this match a colored after effect was given distinctly different from the reading page. This would have necessitated that the final 3-minute record be taken in part at least with a test object having a coloration complementary to the reading page, which would not have been compatible with the purpose of the test. Before beginning each test of the series, the eye was allowed the customary adaptation period without work under the illumination to be tested. The choice of the length of adaptation period was empirical, based on a series of acuity tests, the object being to determine a period the prolongation of which gave no further change in acuity.

In the first series of tests with the illuminants mentioned above, the ordinary green shade of the student lamp was used. However, as the work progressed, the results seemed to indicate more and more clearly that difference in color value must be added to the list of factors which are considered to affect the power of the eye to sustain clear seeing for a period of work. In fact as the tests were conducted, color value was the only variable of any magnitude present from series to series. In any event it was considered advisable to repeat the tests with the color value proper to the illuminant, unmodified by the light which filtered through the shade, even though the position of the lamp was such that a very small part of the light which fell on the reading page was of this origin. From this time on, therefore, an opaque shade of the same size and design and with a neutral lining was substituted for the green shade. The results for the neutral shade only will be given in this paper.²

The reading page illuminated by the different light sources, had the following color values: the "mazda, type B" lamp, an unsaturated reddish yellow; the kerosene flame, reddish yellow with a greater proportion of red and more saturated; the carbon lamp, reddish yellow with less red than the kerosene flame and more than the "type B" lamp; the "type C" lamp, unsaturated yellow, nearly white; and the incandescent "type C2" lamp, noticeably bluish. These estimates of color value are based in part on

²In case of the illuminants used no significant difference in result between the green and the neutral shade was found. However, as a precautionary measure, it was considered best to use the neutral shade throughout.



Fig. 2.—Test room.

a direct comparison, part on the filters that had to be used to make the color match between the test object illuminated by the "mazda, type B" lamp and the reading page lighted by the illuminant to be tested. We have not as yet made a standard colorimetric or spectrophotometric determination.

The tests were conducted in a room 16 ft. 6 in. (5.03 m.) long, 11 ft. 9 in. (3.58 m.) wide and 9 ft. 6 in. (2.98 m.) high. A photograph of the room with an observer, lamp and recording apparatus in position are shown in Fig. 2. The recording apparatus and the fixtures for lighting the test object are, it will be noted, screened from the observer's view.

In the selection and use of observers for all of our work care has been exercised in the first place to choose only those who had already shown a satisfactory degree of precision in other work in physiological optics and whose clinic record showed no uncorrected eye defects of consequence. All have been under 30 years of age. Before being allowed to take part in the actual work of testing, each observer was trained to a satisfactory degree of precision in the 3-minute records under a given lighting condition and in the three hour test under several conditions. In the actual work of testing the results were compiled from a number of observations and the precision was checked up by the size of the mean variation. No results were accepted as significant unless the variation produced by changing the condition to be tested was largely in excess of the mean error or mean variation of each condition tested. This, the accepted check on the influence of variable extraneous factors in work of this kind, was carefully applied at each step in the work. A fuller statement of the precautions that have been used in this and previous work to secure reproducibility of results has been given in various places in preceding papers (see especially *TRANSACTIONS*, 1915, X, pp. 1122-1130).³

³ The data given in this paper were obtained from the observer whose results have been given in the six preceding papers on the effect of different conditions of lighting on the eye. In case of the present paper we have not been able as yet, for lack of time, to check up the results with those of other trained observers. We have, however, in the work on the distribution factors always found the results of this observer to be typical of the group of observers used. Whether or not this will be the case for work in which the distribution factors are not the sole or principal variable, remains yet to be determined. In this regard it is perhaps only fair to

The results for the effect on the eye are given in Table I. The values given in this table are averaged in each case from the results of a number of three hour tests. In order to show the reproducibility of the results obtained and to determine whether the variations produced by the changes in lighting effects are safely in excess of the variations in the test itself, subject to all of the variable factors which may influence it, the mean variation from the average result has been computed in each case. The value of these in per cent. is given in columns 12 and 13 in Table I. This value has been estimated in two ways. In column 13 it is based on the result sought, namely, the mean value of the drop in ratio of time seen clear to time seen blurred. Computed in this way the results indicate whether or not each individual determination has been made with an acceptable degree of precision as compared with other work of its class. In column 12 it is based on 3.5, the value of the ratio time clear to time blurred which has been chosen empirically as the standard of performance of the eye in the 3-minute record before work. Computed in this way the results appear in a form from which it can readily be determined whether or not the work has been done with a degree of precision which is acceptable for the comparative work which is the special purpose of these experiments. That is, to be acceptable in this regard, the variations of the drop in ratio caused by changing the conditions to be tested, must in each case be safely in excess of the mean variation. To make this comparison convenient, the drop in ratio and the mean variation have both been estimated in per cent. on the same base, 3.5.

say that the characteristics of response of the eyes for which these results are given, have been very widely investigated. They have been chosen especially for their normality and practiced precision of behavior and have been used in these experiments under conditions of control based on a very unusual and widely tested knowledge of the factors which influence their steadiness of response. Data on their characteristics of response may be found in more than forty articles. Their spectrum luminosity curve, for example, agrees very closely with the average curve obtained by Nutting for 21 observers. (See Ferree and Rand: *The Selectiveness of the Achromatic Response of the Eye to Wave-length and Its Change with Change of Intensity of Light*, Studies in Psychology, Titchener Commemorative Volume, Brandow Publishing Co., Albany, N. Y., 1917.) At date of going to press check experiments are being conducted on other trained observers.

TABLE I.

Showing the tendency of the different illuminants used to cause loss of visual efficiency, or power to sustain clear seeing.

Type of illuminant	Dominant color	Brightness (cp. per sq. in.)		Time	Working distance (cm.)	Total time clear (Sec.)	Total time blurred (Sec.)	Total time clear ÷ total time blurred	Ratios reduced to common standard	Loss of efficiency expressed in percentage change of ratio	Mean variation (per cent.)	
		Test object	Reading page								Based on 3.5	Based on result sought (drop in ratio)
Mazda lamp, type C	Unsaturated yellow, nearly white	0.003168*	0.003344**	9 A.M. 12 M.	60 60	144.27 142.67	35.73 37.33	4.038 3.822	3.50 3.313	5.34	0.19	3.58
		0.003168	0.003344	9 A.M. 12 M.	60 60	139.0 136.7	41.0 43.3	3.39 3.157	3.50 3.26	6.86	0.43	6.25
Mazda lamp, type B, 15 W.	Unsaturated yellow, slightly reddish	0.003168	0.003344	9 A.M. 12 M.	60 60	138.6 136.2	41.4 43.8	3.348 3.11	3.50 3.251	7.11	0.503	7.07
		0.003168	0.003344	9 A.M. 12 M.	60 60	142.5 140.0	37.5 40.0	3.80 3.50	3.50 3.224	7.89	0.371	4.71
Carbon lamp (metallized filament)	Reddish-yellow	0.003168	0.003344	9 A.M. 12 M.	60 60	139.17 136.33	40.83 43.67	3.408 3.122	3.50 3.2063	8.39	0.323	3.84
		0.003168	0.003344	9 A.M. 12 M.	60 60	138.75 134.12	41.25 45.88	3.364 2.923	3.50 3.04	13.14	0.60	4.57
Kerosene flame	Orange-yellow											
Mazda lamp, type C ₂	Unsaturated blue											

* 1.54 millilamberts.

** 1.63 millilamberts.

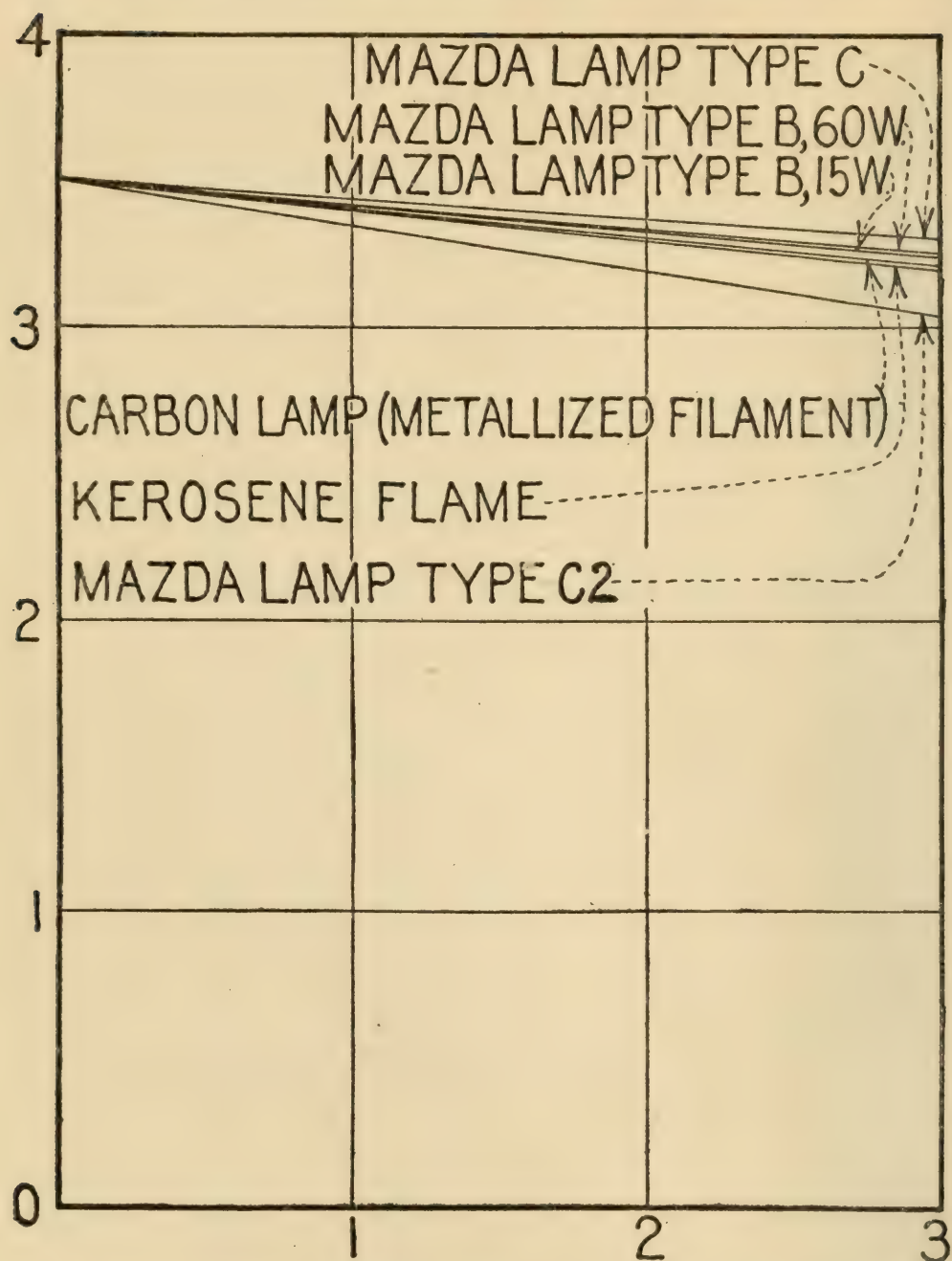


Fig. 3.—Showing tendency of different illuminants used to cause loss of visual efficiency.

In Fig. 3 a graphic representation is made of the results of Table I.⁴ In constructing this chart the total length of the test

⁴A comparison of this chart with those of the preceding papers shows that the order of magnitude of loss in power to sustain clear seeing for the kerosene flame and the type B Mazda lamp (student lamp unit) was about the same as for the best of the opaque inverted reflectors (Mazda type B lamp); and for the type C true tint Mazda lamp, as for the best of the translucent inverted reflectors. The effect for the type C Mazda lamp was slightly better than for the best of the opaque inverted reflectors.

period is plotted along the abscissa and the ratio of the time the test object is seen clear to the time it is seen blurred is plotted along the ordinate. Each one of the large squares along the abscissa represents one hour of the test period; and along the ordinate, an integer of the ratio.

In former papers another method of evaluating the results of the test was employed in addition to the one used above. In this method the ratio of the time seen clear to the total time of the observation is taken as the measure of the eye's ability to sustain clear seeing at the time the test was taken. For the sake of again comparing this method of evaluation with the one used above, a chart has been prepared (omitted from this paper because of lack of space) in which the ratio of time clear to total time of observation is plotted against length of test period. A comparison of this chart with that given in Fig. 2 shows the same order of rating of the illuminants, but a slight difference in the position in the scale given to some of them. For the purpose of discovering what is the best way of treating the results of the tests, several methods have been employed. Up to and including the present paper, however, only three of them have been given in print: ratio of time clear to time blurred, ratio of time clear to total time of observation, and the per cent. drop in the ratio time clear to time blurred. An ultimate decision with regard to what is the best method of treating the results has not yet been reached and for the purposes of this work is perhaps not necessary. From the data given any one of them may be used.

As formerly the work was concluded by determining for the different illuminants used the relative tendencies to produce ocular discomfort with the eye at work. A description of how the determinations were made and a discussion of the method that was used has been given in a previous paper. The results are shown in Table II. In this table are given also for the sake of comparison results expressing the tendency of each type of illuminant to cause loss of ability to sustain clear seeing.

TABLE II.

Showing the comparison of the tendency of the different illuminants used to cause loss of visual efficiency and to produce ocular discomfort. The tendency to produce discomfort is estimated by the time required for just noticeable discomfort to be set up.

Type of illuminant	Dominant color	Brightness (cp. per sq. in.) reading page	Per cent. loss of efficiency	Mean variation (per cent.)	Time limen of discomfort in seconds (reading)	Mean variation (per cent.)	Change produced by changing type of illuminant (per cent.)
Mazda lamp, type C	Unsaturated yellow, nearly white	0.003344	5.34	0.19	116.5	1.30	—
Mazda lamp, type B, 60 W	Unsaturated yellow, slightly reddish	0.003344	6.86	0.43	98.5	1.53	15.45
Mazda lamp, type B, 15 W.	Unsaturated yellow, slightly reddish	0.003344	7.11	0.503	98.5	0.51	0
Carbon lamp (met- allized filament)	Reddish-yellow	0.003344	7.89	0.371	93.0	0.72	5.58
Kerosene flame	Orange-yellow	0.003344	8.39	0.323	90.0	1.11	3.23
Mazda lamp, type C ₂	Unsaturated blue	0.003344	13.14	0.60	54.5	3.70	39.44

DISCUSSIONS.

WM. J. SERRILL: In reading the literature of color in illumination one is impressed with a tendency to confuse color in nature and in art, as a spiritual quality of significant value in human life, with color in illumination or colored light. Of the value of the former, no demonstration is needed; of the latter, it is doubtful if there is a large field, apart from special processes or purposes.

Man's appreciation of color is of immense spiritual and emotional value, and there is reason to believe that its development is by no means complete. Mr. Gladstone, in his *Studies on Homer*, (see the interesting chapter on Homer's Perception and Use of Color) shows that there is ground for the belief that, when the Homeric poems were written, the sense of color values was crude, even in persons so highly civilized as was the author of those poems. Among the common people it is not improbable that everything was black or gray or white. Studies in the coloration of the figures on the pediments and metopes of the Parthenon indicate that, even at the high tide of Greek civilization, vivid colors only were seen. If in twenty-five hundred years, the color faculty has developed to its present stage,—although still varying widely in different individuals,—what wonderful possibilities may the future contain? The promotion of the growth of this faculty is, broadly speaking, one of the chief functions of art. Few tasks are of greater importance, as a keen appreciation of the infinite shades of color is one of the precious possessions of life. Color in the landscape, in architecture and in painting is capable of arousing emotions similar to those educed by music. Under their influence one sees as by an "inner light," the poet's

"light that never was on sea or land."

The question is, what part has colored light to play in this development? I cannot believe that it is destined to be great. The colors of objects simultaneously in the field of vision, whether out-of-doors or in-doors, are so various that any conceivable tint imparted to the light is bound to disturb the relative values of the different objects so as to produce effects that are startling, theatrical or bizarre. Even in nature, a brilliant sunset or sunrise glow on the landscape is viewed as a beautiful phenomenon,

the enjoyment of which is partially due to the consciousness that it is ephemeral. No one would want it to last, or to occur too frequently. In spite of its beauty, we experience a sense of relief when finally

“it sinks into the light of common day.”

Mr. Luckiesh speaks of *painting* with light. It is a pretty fancy, but can it be more? It is sometimes done on the stage, but has it a legitimate place in the home? If our dining room has pink walls, would we tolerate a pink light, which would indeed enhance the pinkishness of the walls, but which would also impart a pinkish tinge to the table-cloth, napkins, and shirt fronts, and which would have no one knows what objectionable effects on ladies' dresses or on the different articles of food? It is said that colored light may replace pigments. Can we ever hope to reproduce the effect of an oriental rug by throwing colored light on a white rug? Is it not evident that interiors must, generally speaking, be decorated for their effect by daylight, and that the best we can hope to do by means of artificial light is to duplicate, as far as possible, the color effects of daylight? The slightly yellow tinge of the common illuminants is popular because it very nearly does reproduce, not the cold day-light thrown from the north sky, but the warm day-light effect that is produced by direct sunshine coming through the windows into the room. Prof. Troland's exceedingly interesting and valuable paper contains significant comment on our preference for a yellowish artificial light. This yellowish light, as is well known, materially changes the color of many objects. Would we care for light of other tints, especially if they were so marked as is implied by the phrase “painting with light?”

In the home, anything bordering on the sensational or the theatrical is recognized as being in bad taste. Persons engaged in social intercourse, at the dinner table or in the drawing-room would generally resent the introduction of anything that would divert their attention from each other, and from their conversation, or, if they engage in card playing, from the game. Any change in the color of the illumination, no matter how gradually, or imperceptibly, or “artistically” accomplished would inevitably produce the effect of a false note in music. Illumination, like the atmosphere, is a medium, very essential to our comfort, but

most enjoyed when least noticed; any material change in either its intensity or color produces an impression as unpleasant as a corresponding change, say, in the temperature of the atmosphere, or in its odor. Effects such as Mr. Luckiesh has in mind, while conceivably possible in highly artistic hands, will be fatally subject to gross abuse, and if colored light, with facilities for its variation, ever becomes commercially possible, one may easily imagine what horrors the future has in store.

Colored light has, of course, a legitimate place before an audience, where the bizarre, the mysterious, the weird, or the grotesque is sought for, or at a masked ball where colored flood lighting is sometimes used with great effect to produce similar sensations. An interesting example of this may be seen in Edgar Allan Poe's "Masque of the Red Death," with its irregular row of variously "color-lighted" apartments, filled with grotesquely garbed figures.

Is there such a thing as color music? Is there any relation between musical notes and the various tints and shades of color? It seems doubtful. Until it has been shown that colors arrange themselves in a definite order, similar to the scale of musical notes, so that a color rhythm is possible, one must be skeptical. There are musical compositions, as Chopin's *Nocturne*, Opus. 37 No. 1 or Grieg's *Death of Aase* in *Peer Gynt*, in which a succession of distinct chords, slowly and regularly repeated, expresses deep feeling, and arouses profound emotion. Can one imagine a gathering of persons, seated in darkness and in silence before a white, or blank screen, similarly affected by a succession of colors on the screen? Is there a language based on color variation by which feelings or emotions may be communicated? Possibly so, but it has yet to be demonstrated.

M. LUCKIESH: I feel that Mr. Serrill has not quite understood my meaning in "painting with light." This conception of the aim of lighting, artistically and psychologically, has arisen from my studies of lighting from the standpoint of *effect*. Lighting consideration too generally stops at the fixtures or on the workplane. After all, our impression of lighting is due to that which we see and we see *effect*. For this reason I have contended that decoration and many esthetic principles are closely related

to lighting and commend the idea of painting with light by means of certain distributions of light, shade and color (as obtained from light) in the scenes before us. This is just what is being done when we think of effect but to summarize lighting as painting with light brings to many a new conception of the effects and possibilities of lighting.

C. O. BOND: I wish to ask if Miss Irwin is familiar with the Chinese and Japanese color effects either by direct contact with those people, or from reading upon the subject, so that she could inform us whether they had any regular scheme of producing emotions by means of the colors used on their lanterns. Not that I wish to contrast the validity of their possible method with Miss Erwin's, but merely as a matter of interest.

BEATRICE IRWIN: I have lived in China and Japan and have studied their arts and have spoken of them in my book, "The New Science of Color." The Orientals understand and express the psychology of color not only in their lanterns but in their embroideries and costumes, in which one finds the greatest intensity and variety of color combined, without any disagreeable effect. Why? Because they knew how to balance color in harmonic values, and the relations of colors to each other.

M. G. LLOYD: I want to ask Miss Irwin if she will explain the significance of Fig. 3.

BEATRICE IRWIN: There are three systems of color, or color keynotes we may say, that respectively affect the physical, the mental, and the nervous organisms. Now these are classified in this chart, in that manner. No. 1 represents, the physical system, or the seven beams of color that are keynotes. In each of these systems there are subdivisions of color. In the physical system we get as sedatives, lead gray, brownish purple, terra cotta, and moss green, as recuperatives we find golden brown and turquoise blue, as stimulant, vermilion. The colors that affect the mental system or mental activity have been found as follows, olive green (sedative), recuperatives, rose madder, fawn, royal blue and emerald green, the stimulants are violet and chrome yellow.

The color keynotes affecting the nervous system, which I have called the nervous colors, are moonlight blue, (sedative), recuperatives, orange, flame rose, and the stimulants are, Nile green, mauve, citron and azure. This chart as I say is based upon the result of a great deal of experiment with color developed through vibratory tests.

I note Dr. Trolland's paper. He does not state whether his experiments were made through the medium of light or color environments.

WILLIAM A. DURGIN: The wide diversity of doctors associated in this organization has been especially well brought out by the range of papers and variety of viewpoints in this discussion. One large class of membership, however, has hardly been represented; the central stations and their customers. May I speak for a moment, then, in the interest of perhaps a million people in New York, Philadelphia, Boston and Chicago?

Most of these are not at all impressed by a 5 per cent. or 10 per cent. change in fatigue; most of them would be merely puzzled if you spoke of affective values of color tone, while neither their incomes nor their imaginations stretch to the consideration of delicate interior decoration schemes. But many of them do know, or think they know, that under the old kerosene flame the home was cozier. The light seemed better for reading, sewing, and the other home activities.

These people, entering a room lighted with a warmer yellowish tone, are enlivened. This is hardly any subtle reaction of the colored radiation upon the physical self of the observer, but rather the effect of the colored light upon the appearance of the room, and particularly upon the appearance of the faces of the people in it. If the color of the light suppresses the fatigue tones in the faces, and makes them look refreshed and invigorated; if the general atmosphere simulates that of earlier firelight and lamplight evenings; it follows inevitably that you have a better time while you are in that room.

As one of the previous speakers has suggested, there is nothing particularly new in this conception, and various movements are under way to realize the advantages of warmer light in our daily living. One of these has been undertaken by our sister society,

the National Electric Light Association. The Lamp Committee of that body, working through a special Sub-committee on Colored Bulbs for Incandescent Lamps, has distributed samples of yellow toned lamps to the four largest Central Stations: Boston, Philadelphia, Chicago and New York. The tones range from the carbon lamp color through that of kerosene to a still deeper yellow. Some seventy people have observed the effect of these lamps under home conditions, indicating the depth of yellow which seems to them preferable. A large majority of the observers have agreed that the kerosene flame color is best.

With this limited but still rather representative verdict, the Committee is now going to the lamp manufacturers with specifications for natural glass which shall realize the kerosene tone. It is hardly to be expected that such lamps will be in regular production until more normal manufacturing conditions obtain, but there seems no doubt that we shall ultimately have such a lamp widely available. Probably the lamps will not be of the most aesthetic shade; the affective value is quite problematical; but if we may turn for a moment from the ultra-ideals of art and science, these lamps will make for a cozier atmosphere in many homes, and perhaps even a slight improvement in the life of a few million people may be considered worth while.

M. LUCKIESH: In my introductory paper I have touched upon various aspects which have been discussed in the other papers but I would like to record a few other remarks. Prof. Richards has done well in recording so much in his paper of a subject which is very extensive but to discuss this subject completely is quite beyond the limits of a brief paper as Prof. Richards has stated.

I am quite in accord with Miss Irwin's hopes for the future of color in a field which she has discussed. I have expressed my views regarding this field in my paper and elsewhere but would like to sound a caution. In the first place Miss Irwin appears to believe that she is dealing with a "new" subject but, in fact, this aspect of color is perhaps the oldest of all the many aspects in which man has become interested. The first savage who placed a red feather in his hair recognized the impressiveness of color in a slight degree at least. I believe that it is well to experiment

radically in this direction discussed by Miss Irwin but before some of her conclusions are generally accepted among scientists—the discoverers and organizers of facts—more adequate proof must be submitted. I have contended that no more interesting and fruitful field is open to the psychologist than that of color.

Dr. Troland has given us a masterful paper and those interested in lighting may expect interesting developments in fields pertaining to color as capable psychologists are becoming more interested in this field. This is the most extensive unexplored unknown in the whole realm of lighting and vision.

Mr. Priest has presented a resumé of the standardization necessary in color-science—a plea for which I have sounded many times in various discussions of the subject and specific investigations which are to be found elsewhere. Our laboratory has long been engaged in work in lighting, vision, color, photometry, etc., and we have recognized the necessity for standardization and analysis in various directions pointed out by Mr. Priest. There is a growing recognition of the importance of analyses of colored media, etc., as is evidenced by the many analyses that we have made for others. Mr. Priest has necessarily limited his references to much of this work, but they may be obtained readily by those specifically interested.

Drs. Ferree and Rand have given us another paper of their interesting series but there is little to discuss from the standpoint from which I am specifically interested because as Dr. Ferree has stated the results are not sufficiently different for the various illuminants to warrant much discussion. A priori, I would not expect an illuminant of approximate daylight color to be less fatiguing than one of a decided tint. Inasmuch as it appears reasonable to consider that the eye is more adapted to daylight than to illuminants of pronounced hue I would decide from the results of Dr. Ferree that the differences in the fatigue-effects are too small to be determined decisively by any method yet devised for measuring fatigue. It may be of interest to recall the results of some experiments which I made during a recent winter upon myself and another subject. Seated in a comfortable position in our home we read evening after evening under different illuminants (deep yellow, carbon lamp, tungsten lamp, artificial daylight) the sources being behind and above us. The conditions

were maintained as constant as the circumstances permitted by adopting various simple expedients such as always facing a plain wall of a brownish-gray. Our conclusions in regard to fatigue were that the deep-yellow was most fatiguing of the illuminants used with the carbon, tungsten and artificial daylight ranking in regular order with the last one least fatiguing. (TRANS. I. E. S. Vol. 10, 1915, p. 1015.) These results were quite convincing to the subjects under the conditions but, of course, it was realized that the method was one lacking in refinements and controls so necessary in order to be generally acceptable and convincing.

In regard to Dr. Ferree's introduction I wish to state that the liking for yellowish or "warm" light has been due chiefly to esthetic rather than to physiological satisfaction.

In general, it is gratifying to note the increasing interest in color in this Society but let us proceed carefully and be sure of our ground when others are involved. Individually we may do and like what we please.

BEATRICE IRWIN: I am sorry that Mr. Luckiesh objects to the term "New Science," but as I said in my paper it is based upon the fact of my specialization in color. In the past we have had generalizations, but my work aims at specialization and I claim that red can be a sedative and a recuperative color as well as a stimulant, by which term only it has been recognized hitherto. This specialization was challenged by physicians in San Francisco who attended my lectures at the International Exposition there, and I was invited to test my claims in the laboratory of Dr. Abrams by means of two instruments, the energimeter and the pneumograph. I took the nine colors, three reds, three greens and three blues, respectively called sedatives, recuperatives and stimulants. It was found that the tests justified my classification, and so it is in connection with this specialization that I apply the word "new," to my work.

IRWIN G. PRIEST: Mr. Luckiesh speaks of my paper as "resumé." There is perhaps a chance that the use of this word may cause some misunderstanding. I had no intention of preparing a "resumé" of the subject; and would point out that the title and the opening sentence of my paper are both very

explicit in limiting its scope. The limits of the paper have permitted only a bare catalog (not description) of our own work and plans, with no thought of treating the subject more generally or compiling references. A properly balanced "resumé" of the subject would be a very much larger and, in general, a quite different paper. A consideration of the avowed scope and purposes of the paper will perhaps save it from criticism which might be due if it were regarded as a more general "resumé."

It seems to me that Mr. Serrill's remarks on certain proposals for the use of color in lighting are quite well advised and constitute a warning which we will do exceedingly well to consider and heed.

C. E. FERREE: The subject is new and prior to further experimentation I hesitate to say more with specific reference to the results given than I have already said in the foregoing paper. The following general comments, however, may not be out of place.

(1) It may not be readily understood why the power to sustain clear and comfortable seeing should be affected by the color value of the light illuminating the page. At least one factor in this effect may, I think, be pointed out at this time. The reading of black letters or other characters on a page which represents any considerable degree of coloration due to the composition of the light illuminating the page is a peculiarly baffling experience. There is an unclearness which is not the blurring of bad focusing nor of faulty fixating, but which seems to be a matter of the ease or rather lack of ease with which the details of the retinal picture are discriminated. Unclearness or difficulty of discrimination from any cause whatever leads reflexly to muscular effort towards a corrective readjustment which of course in the case under consideration comes to naught and only induces fatigue. In the work so far, only a part of which is reported in the foregoing paper, we have found that in case of a given color the power to sustain clear and comfortable seeing decreases with increase of saturation of the color, but that independent of saturation some colors affect the eye more than others. The worst effects thus far have been obtained with colors towards the short wave-length end of the spectrum.

(2) Some discussion arose on the floor with regard to the coloration of the page illuminated by the C-2 lamp. In considering the relation of filters to the saturation or coloredness of the sensation aroused by the light transmitted, the effect of intensity of light should be kept in mind. That is, although the composition or relative proportions of wave-lengths may remain the same, the coloredness of the sensation aroused (even the hue) varies with the intensity of the light. For example, in case of spectrum light, if one starts with intensities which give the maximum color in sensation, and either increases or decreases the intensity, the coloredness of the sensation aroused decreases, the decrease in saturation taking place faster with increase than with decrease of intensity of light. If the intensity is decreased the colors lose saturation and at low intensities are seen as grays. If it is increased the sensations aroused from a point in the blue green to the short wave-length end of the spectrum decrease in saturation, in some cases also change slightly in hue, and become white at high intensities; and the colors in the green, the yellow green, yellow, orange and red parts of the spectrum pass through yellow towards white. This phenomenon was mentioned as early as 1823 by Purkinje¹ in his original observations on the change in the saturation, hue and relative brightness of colors produced by changes in the intensity of light, and may easily be demonstrated if means are at hand to make the needed changes in the intensity of the lights employed. Obviously, then, in case of a given color of bulb and candlepower of source the colored-

¹Purkinje. *Beobachtungen und Versuch zur Physiologic der Sinne*, 1823, I, p. 109. Purkinje's observations cover the following points. (1) The relative differences in the brightness values of the colors at different intensities. (2) The effect of change in brightness on the saturation of the colors and the differences in the effect for the different colors. (3) The changes in hue produced by changes in brightness. With regard to this effect on both hue and saturation, the variable brightness component may be introduced with equal success, so far as can be determined, as a brightness after-image, as brightness contrast (physiological induction), by adaptation, by the admixture of white light, or by changing the intensity of the colored light. In short, the effect on hue and saturation may be obtained in any of the known ways in which the brightness or achromatic value of the sensation may be changed.

Since the publication of Purkinje's observations in 1823, a rather extensive literature has accumulated on the effect on hue and saturation of changes in the brightness of the color. (Brucke, 1849, 1851, 1865 and 1878; Dove, 1852; Helmholtz, 1852, 1866 and 1885; Aubert, 1862; Lamansky, 1871; von Bezold, 1873; Dobrowolsky, 1876 and 1881; Chodin, 1877; Donders, 1877 and 1881; Rood, 1880 and 1899; Bull, 1881; Albert, 1882; Fick, 1888; Ebbinghaus, 1889 and 1893; Hegg, 1892; Abney, 1893; Tonn, 1894; Vogel, 1895; Lane, 1900; Fernald, 1905 and 1908; Revesz, 1907; Ferree and Rand, 1911 and 1912; Rand, 1912 and 1913; etc.) In our previous writings on the subject (*Journal of Philosophy Psychology and Scientific Methods*, 1911, VIII, pp. 294-297; etc.), we have discussed this phenomenon as an effect, in part at least, of the achromatic upon the chromatic component of excitation, and have attempted to determine roughly the physiological level at which the action takes place. In this phenomenon we have apparently one more example of the interactions on each other of the physiological excitations produced by the light waves.

ness of the reading page may be expected to vary with the distance of the page from the source, a decrease in the distance, for example, increasing the brightness but decreasing the coloration of the page if, prior to the change, that intensity of illumination which is most favorable to the chromatic response in question has been reached or exceeded; and a glass showing a certain selectiveness of absorption will, aside from possible differences of composition of light, give a different effect on the coloredness of sensation when used in connection with sources of different candlepower. This dependence of the saturation and the hue of the color sensation upon both the composition and intensity of light is a fact which should be kept in mind in problems such as are dealt with in the preceding paper. A reading page, or a surface coated with magnesium oxide, illuminated by a blue bulb lamp may match in coloration by direct comparison a similar page or surface illuminated by a given composition and intensity of daylight and fail to match it in saturation or even exactly in hue when a different intensity of the artificial light is used. This fact may underlie some of the difference in opinion that exists with regard to the comparative coloration of the reading page when illuminated by daylight and the mazda C-2 lamp. A statement that a match in saturation and hue has been made between two lights is not complete unless the relative intensities at which the match was made are also given.

(3) If the degree of coloration of the reading page is a significant factor in the power of the eye to discriminate the printed characters with ease and comfort, as we have good reason to believe it is, the inadequacy for our purpose of a spectro-photometric specification of the source should from the foregoing considerations be obvious. It should be supplemented by some type of colorimetric specification of the page itself.

(4) In speaking of his home observations on the comparative comfort of reading by artificial daylight, mazda, type B, and carbon lamps, Mr. Luckiesh fails to state how the artificial daylight was obtained. Our tests have been conducted only with the mazda C-2 lamp and under the conditions of intensity and distribution specified. It may be that other existing approximations of daylight will give a different result. We know nothing, moreover, of the comparative selectiveness of absorption of the

reading page in the two cases, nor of the relative intensities of illumination of the page with the different lights used by him. The walls of his room, he states, were a brownish gray. This, depending on the conditions of distribution, might very well have caused a change in the relative proportions of the blue and reddish-yellow components of the light falling on the page. The walls and ceiling of our test room were neutral as to color and the type of distribution was such that they could not in any event have influenced to any appreciable extent the light which fell on the page. The general nature of the judgment upon which his estimate of comparative comfort was based, he has already noted.

(5) Mr. Luckiesh is quite right in cautioning us that the problem of lighting is a complex one and that many interests and factors should be considered. The purpose of this Society, and I include in this the investigator as well as the producer and distributor, should be to consider fairly the best interests of lighting from all points of view. The problem presents many aspects, and poise is needed lest one's judgment be biased by an undue enthusiasm for some particular feature or point of view. It does seem to me, however, that it is wise to distinguish between lights used for esthetic and decorative purposes, and those used for reading and working; and to keep this distinction clear in our teaching and practice. This is, perhaps, Mr. Luckiesh's purpose. In this connection it should also be borne in mind that while small differences in conditions are of comparatively little consequence to the normal eye, they may mean a great deal to a sensitive eye or one which is already overstrained.

(6) In our introduction we were careful to specify that many laymen and certain lighting specialists and ophthalmologists had contended at different times in a public way that light of the color value of the older illuminants is best for the eye. The reference to recent papers in the Society, as was indicated in the introduction, was merely by way of noting that there is at present for some reason a growing tendency among lighting engineers and producers to simulate the older illuminants.

(7) As Mr. Luckiesh states, the differences in result are extremely small as compared with those previously obtained for differences in shading. Greater differences have been gotten,

however, in case of illuminants giving greater differences in the coloration of the reading page.

In the above comments I have purposely and somewhat laboriously emphasized the influence of the actual coloration of the reading page on our power to sustain clear and comfortable seeing. It is a factor in acuity, more particularly in the power to sustain acuity, to which as yet little attention has been paid. (*cf.* this TRANSACTIONS, 1913, VIII, p. 144.)

E. F. KINGSBURY: I read with much interest Dr. Troland's paper on the Psychology of Color, especially his discussion of successive contrast and association as factors in determining color.

I would like to ask the author why we should associate blue with evening light (especially artificial light) in preference to the reds and yellows that we, as a race, have been accustomed to in our artificial illuminants for a very long time? During several thousand years the human eye has been much exposed in the night to both strong and dim lights that are far yellower than the sun's, and it would seem they should have some influence in determining our color associations.

I agree that contrast is a very important factor in some cases in making the yellow lights yellower and the white or blue ones bluer than they would otherwise be. However, the general shift of evening and dimmed lights is toward the blue. Daylights we call blue; the tungstens, the mantle, the arcs we call white. It shows that without the assistance of contrast, our judgment of absolute color is as erratic as that of absolute brightness. Psychologically we cannot differentiate between whites and near whites.

To test the importance of adaptation or successive contrast as a factor in the blueness of artificial daylight, I illuminated a white surface with artificial daylight. I then adapted myself to sunlight and looked at the white surface. Of course it looked blue and according to the decay of adaptation it should look at least some blue for a long time. However, I then held a blue glass before one eye for a few seconds. The blue artificial daylight immediately turned white or yellowish, depending upon the time and intensity of the exposure, though with the unexposed eye the surface still looked bluish. This white or yellow, however, quickly turned back to the original blueness in spite of the law

of adaptation that should have prevented it if it had been an important factor, and the true asymptote was a white. The easy destruction of the bluishness by the blue glass, a raise in intensity, or field limitation would seem to be against association.

It should not be forgotten that the eye with unlimited field and range of pupil adaptation is in the best condition for the Purkinje phenomenon to have its influence. Even in bright moonlight which seems so blue we are well above its threshold, while under the ordinary intensities of artificial illumination, it is prominent. At these latter intensities where we do our heterochromatic photometry the field has to be restricted to avoid it. In evening light outside we are oscillating on the threshold of the Purkinje phenomenon. I cannot see, in view of this, how we can ordinarily expect a white to remain so as the illumination is lowered, without specifying the conditions as rigidly as in heterochromatic photometry.

I do not believe there is only one temperature at which a black body will appear strictly white. The diversity of lights we now call white indicates that there is a range of perhaps several thousand degrees in which only the conditions have to be right for it to look white. We say a black body or a near black body is at "white heat" when it is as low as 1500°C . and it really does look white.

The author lays considerable stress on Hering's observation that sunlight is yellowish because when it is dimmed it turns blue. If a light that looks perfectly white but is bluer than sunlight is dimmed, it will also turn bluish.

Is it not being assumed that the blue from dimming is due to contrast with a real yellow, whereas it must first be proven that the blue is not a real and permanent one because if it is stable, then we might easily expect the sun to be yellow by contrast when it is really white? The blue glass experiment, mentioned above, performed with a dim bluish sunlight shows it is a permanent blue.

I. G. PRIEST: It seems to me that the point of view adopted toward the definition of "color" in the introductory paragraphs of Dr. Troland's interesting paper is preeminently rational and convenient. There is apparently however a slight difference in our concepts, for in Dr. Troland's statement: "The word

of seen space, out into which we look, presents itself to us at each moment, as a pattern of colors and luminosities,," I would delete "and luminosities," for I would regard "luminosity" (brightness, brilliance) as one of the three-color characteristics. I believe a definite subjective definition of "color"¹ to be the logical and indeed necessary starting point of a consistent system of colorimetric nomenclature. By strict adherence to this concept and a consistent system built on it much confusion of thought and words may be avoided.²

I would particularly commend Dr. Troland's criticism of Planck's use of "color" as a synonym for wave-length. In this connection I would also point out that the conventional use of "gray radiation" to describe spectral energy distribution giving rise to anything but gray sensation is very repugnant to those interested in formulating a colorimetric nomenclature.

Dr. Troland's contentions in regard to "artificial daylight" at night and his emphasis on "the importance of association and expectation in determining our experience" are very pertinent. The facts which he points out in this connection are facts and must be considered even though they may not at first sight be clearly comprehended by the physicist or engineer.

I am particularly interested in Dr. Troland's proposal of a definition of "white light" on a psychological basis because I have been making some experiments with a view to obtaining the data on which to base such a definition.

My experiments have not yet reached the stage where I would be justified in inferring definitive, unqualified conclusions; but since they bear so directly on Dr. Troland's discussion, I am prompted to describe my own experiments in their present status, without insisting at all upon their significance.

The plan is to determine the spectral distribution of energy which the observer calls "white or gray" (*i. e.* neither bluish nor yellowish), this distribution being adjustable by continuous variation from bluish to yellowish by the observer himself.

Observations to date have been made only under the following special conditions:

1. The field viewed is circular and subtends an angle of 1° at the eye.

¹ See Century Dictionary.

² See further, Priest, "A Proposed Basic Nomenclature for Use in Colorimetry," now in preparation.

2. The light field is surrounded by a completely dark field and both eyes are completely shaded from extraneous light. There is no comparison light in the field.

3. The average field brightness is about 500 meter-candles but varies with the color setting from about 250 to 1000 meter-candles. This is viewed through a circular pupil 1 sq. mm. in area.

4. No precautions have been taken to bring the eye to any particular state.

5. Color is varied by the rotatory dispersion method using apparatus previously described.³ The quartz thickness is 1.000 mm. The observer sets the angle ϕ to the transition point between blue and yellow. (He is requested to set to "distinctly" blue and "distinctly" yellow and judge the half-way place mechanically; but is warned not to fatigue his eyes by setting to the saturated tints of either blue or yellow).

6. Four independent settings are made in sequence and the mean angle taken.

Eleven subjects (excluding one color blind who could not make the setting at all) have been examined. Of these, three have been examined three times on three different days; six others on two days; and the remainder only once.

The mean spectral energy distribution thus found⁴ is almost identical with that of a "black body" at 4000° (Planck's formula).

The "bluest" white found among all of these settings is "yellow" than direct sunlight at the earth's surface.

Two observers made very "yellow" settings; one which would about match a gas-filled tungsten at 22 lumens per watt; and another which would correspond to even lower efficiency, perhaps about 15 lumens per watt (not accurately known). The former of these made almost the average setting on the following day. The latter has not been re-examined.

Excluding these extremes the other determinations were comparatively concordant.

It appears that these experiments, insofar as they indicate anything, point to quite the contrary of Dr. Troland's (and Hering's) hypothesis that "psychological white" is "bluer" than sunlight. However, it must be emphasized that a great deal depends upon the special conditions in such experiments, and I think we can safely draw neither a positive nor negative conclusion at present. The question deserves further attention

³ *Phys. Rev.* (2) 9, 342.

⁴ Computed as indicated in *Phys. Rev.* (2) 10, 208.

and I think the rotatory dispersion method is a good means of attack. We expect to continue and extend the investigation.

This same method may afford Dr. Troland a convenient means of working with a given "black body" distribution which he says has been lacking to him. I have not succeeded in exactly matching "black body" curves at all temperatures but can get much better spectral matches for 5000° than are obtained with colored glasses. For 4000° the agreement between the Planck curve and $E_A \sin^2 (180 - a)$ is very close. E_A = relative energy, acetylene; and a = specific rotation of quartz.⁵

The spectral energy distributions obtained by this method with different sources and many different thicknesses of quartz and different values of ϕ have been computed at the Bureau of Standards and are available for reference to those interested in this matter.

L. T. TROLAND: I wish to thank Messrs. Kingsburg, Luckiesh, Priest and Serrill for their careful consideration of a paper which, owing to the pressure of war duties, was only very hastily prepared.

The exact setting of the principle of association in my discussion of the psychological blueness of evening light was perhaps not made sufficiently clear. Simple association, as Mr. Kingsbury points out, would of course tend to make us *add* yellow to the visual perceptions of evening, rather than subtract it. This might occur as a result of individual experience, but the rejection by modern biology of the doctrine of the transmission of acquired characters would not be consistent with the idea, which Mr. Kingsbury suggests, that it could result from the experience of the race.

My theory of the action of association, in the present case, however, is slightly more complex. I suppose that experience has taught us, individually, that to gain a correct notion as to the color of objects viewed by the usual yellow artificial light, we must subjectively subtract yellow from our naive sensations, derived from these objects. The psycho-neural mechanism seems to be constantly in quest of impressions which repre-

⁵ For significance of this formula see *Phys. Rev.* (2) 9, 341, and (2) 10, 208.

sent the inherent nature of objects, independently of the peculiarities of the medium through which they are perceived. This is necessary as a condition of correct response and safety. Learning to subtract yellow from our ordinary crepuscular perceptions demands an association of this modification of sensation with evening time, or with any large, general reduction of illumination, and this associative tendency is so strong that it is effective even when the artificial illuminant is actually not yellowish. In this latter case, the result is naturally the production of a psychological blue.

This kind of use of the principle of association is consistent with the modern idea that physiologically, association involves a linking together of different reflex processes by their connection with a single type of stimulation. "The subtraction of yellow" is not an "idea" but rather a psychophysiological process which is set off by a general reduction of illumination, or perhaps even by a perception or belief "that it is evening." Our description of the process would conform more closely to the ordinary conception of association if we translated the phrase, "the subtraction of yellow," into its equivalent, "the addition of blue." I do not wish, however, to exhibit undue faith in the validity of the associative explanation. The explanation based upon the supposed yellowness of sunlight, and the chromatic dimming effect is equally interesting. The latter involves primarily retinal factors, while the former depends upon central processes.

Mr. Kingsbury finds that the apparent blueness of artificial daylight, following adaptation of the eye to sunlight, can be temporarily but not permanently annulled by a brief exposure of the eye to a saturated blue of lower intensity. The apparent yellowness which immediately succeeds the strong blue stimulation of course requires no comment, but its eventual replacement by a bluish tinge instead of a white or faint yellow is remarkable. It would seem to me that, superficially considered, this would argue for the associative explanation. We cannot expect the associative "yellow subtraction" to completely counteract the powerful yellow after-effect of the saturated blue, until this effect has had time to decay considerably; but the associative tendency may quite rationally be regarded as permanently lowering the "asymptote" into the blue.

Some facts suggest that a momentary, although powerful, adaptation to blue may not actually obliterate the retinal after-effect produced by a prolonged stimulation with yellow. In physics, we find that mechanical and dielectric strains set up by prolonged action, often cannot be wiped out by the brief application of forces tending to relieve them, even when the immediate after-effects of the latter forces for a time predominate.

I am not positive that I understand Mr. Kingsbury's appeal to the Purkinje phenomenon. This phenomenon is usually attributed to the shift from cone to rod visibility, and such a shift should not result in any change in color (unless desaturation is so classified), since rod vision is ordinarily supposed to be achromatic. König, as I have pointed out in my paper, declared that the rod sensation is bluish, but it was one of my purposes to show that acceptance of his contention is not necessary.

With regard to the temperature at which a black body will appear white, I am quite willing to admit that the differential threshold which will condition the determination of this temperature, is a large one, especially when expressed in degrees Centigrade. However, this only makes it difficult and not impossible to identify the temperature in question. Mr. Priest has apparently found it feasible to attack this problem experimentally.

Mr. Priest finds contrary to my expectations—that the radiation judged as white by his subjects is yellower instead of bluer than sunlight. His measurements were naturally taken with a small field with dark surroundings, under which conditions the subject might acquire the same mental set which accompanies visual quality judgments in the evening. In this case, we should expect the subject to pick a sensory yellow as a perceptual white. It would be interesting to make determinations of this sort with the entire retina flooded with light, and also to apply Hering's dimming criterion. The latter should provide a test the results of which should be less contaminated by possible central influences. I note that Mr. Kingsbury obtained blue upon dimming a "white" which was considerably bluer than sunlight.

The problem as to the definition of "white light" is of course one into which there must necessarily enter some degree of

arbitrariness. We may eventually settle upon some sort of "best representative white," which combines the results of a number of criteria. However, in problems of this sort, an hypothesis will often prove of practical value as a guide. The hypothesis which I had in mind assumes that the maximum of the cone visibility curve originally coincided with the maximum of solar radiation—a condition of maximal efficiency—and that color vision is a device by which the organism detects a deviation of spectral distribution from that of the sun's radiation. The cooling of the sun which may have occurred since the visibility curve was established would naturally make our present sunlight retinally, if not cerebrally, yellowish.

I am very glad to find that Mr. Priest agrees with my adverse criticisms of the present color and radiation terminology among physicists. I may say also that I actually concur with Mr. Priest in regarding "luminosity" as a color characteristic, although this definition of the word "color" (coinciding with Hering's usage of "*Farbe*") is still so uncommon that I hesitated to employ it in my paper. Otherwise, I should have spoken of a "pattern of *hues*, saturations, and luminosities....."

Mr. Luckiesh is quite correct in his characterization of the field of color psycho-physiology as an "extensive unexplored unknown;" and we need many more scientifically equipped explorers to attack its problems. I am convinced that such explorers will make many definite, interesting, and practically valuable discoveries as rewards for their efforts.

Mr. Serrill rightly emphasizes the importance of the familiar as well as the novel as a condition of satisfaction in illumination. With regard to "color music," while it is unlikely that successions of colors can ever have the symbolic and representative power possessed by phonic music, it is nevertheless conceivable that they may bear some affective fruit which is not nourished by the emotions. The beauty of color-patterns in space is usually not evidently dependent upon an emotive or intellectual appeal. Consider, for example, the fascination of the kaleidoscope. On the other hand, the beauty of a great deal of phonic music seems to be wholly sensory.

C. R. CLIFFORD: It is with much interest that I have studied the papers of the color symposium, and can find little to criti-

cize; what is said is doubtless authoritative, so I will, if you will permit me, discuss not the things you have said, but the things that have remained unsaid.

First: No lighting will ever be satisfactory for its color effects without proper consideration for the color of the background, which the engineer is too apt to ignore or to assume as negative or neutral. On the contrary, lighting is only a part of a decorative co-ordination and must be undertaken with a clear conception of the results of a finished work.

Second: It is wise always to consider not only the character of the room, but I might say, its topography. The decorator always determines whether, by reason of its cold northern exposure, a room needs the artificial sunlight effect of yellow, orange or red, or whether by reason of its southern exposure, it needs neutral or cold colors and having introduced these colors as a permanent part of the day-time decoration of a room, the night light must be selected in consideration thereof, to harmonize and not to destroy.

I have seen rooms that have been delightfully furnished in side-walls and upholsterings, simply killed by the lighting "expert" who was obsessed by the love of some particular tint.

Third: There are rooms moreover that are so small that the decorator treats them with distance effects—grays or pastel shades. Here again all one's theories of fundamental color lighting must be subserved to the fact that in considering lighting we must consider the accommodation of light to the existing color environment.

It is seldom that we have conditions of colorless environment which permit the illuminating engineer to express his independent color theories. Where the decorator has already presented a distinct color scheme, the engineer must check his individualism or chaos will result. Therefore, I consider it absolutely necessary that you work with the decorator.

You are but recently considering this subject of color, while the decorators have studied it for years, and I hope that you will see, as I see, the great good results which may accrue through collaboration.

Fourth: We do not all agree with Robert Burns regarding man and the clothes he wears. Appearances go a great

way, and whatever you may affect in lighting will be always handicapped by the atrocities and anachronisms of the fixture manufacturer. There is no one factor so troublesome to the decorator. You, for example, are concerned with both the practicability of good lighting, where good lighting is needed, and the charm of a tinted light where decorative quality is necessary. The fixture should be always acquiescent. It should not dominate. It should simply fit into the environment.

Therefore, I would urge you, if you are to get the best results, bring into your symposium not only the decorator but the fixture man and endeavor to arouse in him the aspirations and standards which unquestionably are arising in your society. Researches and discussions will result in nothing unless you bring into co-operative unity the arts and the industries.

We are living in an age when no man who would accomplish anything can do it alone. If it is desirable to understand the charm of color and to practice an advanced scheme of lighting that may have esthetic influence, no man can work independently. No man knows enough. The scientist may comprehend the psychology; the technician may know the mechanical; the artist may appreciate harmony; but do any or all of them know enough to properly apply their knowledge to the selection of fixture mediums that will breathe the spirit and reflect the period style of a Jacobean interior, a William and Mary, Queen Anne, or French Renaissance? Do they understand the sort of a fixture for lighting a room of the Francis I style, Charles II or early Victorian?

You can give us the science of lighting, but the fixture men should furnish you with mediums through which to express it; and above all I commend you to take into your conferences the decorator, who presents not only the environment which you are to handle, but who is critic, judge and counselor, and the man who in all of his work considers the character of the household, the character of the occupants, the use of a room and its temperament, and to whom light is often a means to expression, as the artist employs it to show sunrise or sunset or dusk effects, to express the sobriety or gayety of a room according to its character, its occupant or its specific purpose.

ECONOMICS IN THE OPERATION OF LARGE
LIGHTING INSTALLATIONS.*

BY CLARENCE L. LAW AND JAMES E. BUCKLEY.

Synopsis: This paper describes the executive details and routines necessary to the economic operation of lighting installations served by central stations with particular reference to the systems of the Illuminating Engineering Department of the New York Edison Company. Surveys and subsequent recommendations based thereon cover the preliminary steps and layout of a new installation or in the improvement of an old one. The paper includes sample illumination tests, tabulations and curve sheets showing location of lamps, horizontal intensities, average foot-candles, current consumption and weather charts.

INTRODUCTION.

The Bureau of Illuminating Engineering of the New York Edison Company is engaged in general illuminating engineering work. Sometimes this involves design of new lighting installations; again, it may involve improvement of existing installations to secure better illuminating effects, and still again it may involve the introduction of economies to reduce costs. As the latter phase of the Bureau's activity is of particular interest at this time, the authors have been requested by your Committee on Papers to describe it. This paper in consequence will be devoted almost exclusively to an account of the methods employed in cases where a reduction in the cost of lighting is to be effected. In these cases the need for economy by no means eliminates other considerations although it must be admitted that sacrifices are sometimes made, such as the details of esthetics, in order to bring about a result. It is pointed out also that invariably installations investigated are ones needing remodeling, having been installed some time ago previous to the advanced stage of the lighting industry.

The writers have endeavored to present briefly the methods followed in preparing data and maintaining records of the lighting consumption with a view to eliminating any misuse of the installation or waste which might be caused by the use of inefficient lamps, incorrect fixtures, improper glassware or careless operation of the system.

The classes of installations particularly mentioned in this paper

* A paper prepared for the 1916-17 Correspondence Convention of the Illuminating Engineering Society, and circulated among members of the Society and others who were thought to be interested. This paper was also presented by the authors before the New York Section September 13, 1917.

are office buildings, loft buildings, hotels, and clubs having buildings of their own. These types are taken because they represent the greatest number of buildings where these investigations have been conducted.

The following table will give an idea of the importance of the lighting load as compared with the total consumption of a building:

TABLE I.

	Including electric elevators (Per cent. total consumption)	Excluding electric elevators (Per. cent. total consumption)
Loft building	43	—
Office building	59	98
Hotel building	47	90
Club building	—	82
Department store building.....	75	79

SURVEYS.

When a request is made for an investigation or the supervision of a lighting installation, the first step in the procedure is to make a thorough and complete survey of the entire electrical equipment. This survey is made in detail, the location of lamps, the number, size, and type is noted, also the style and location of the fixtures.

These surveys are made by survey inspectors who are specially trained for this kind of work, as it is necessary to know and recognize the various types of lamps and sizes, for it is not always convenient to get close enough to a lamp to determine what it is by the label. A knowledge of the sizes and contours of bulbs is essential on the part of the inspector.

In making these surveys difficulties often arise due to the apparent lack of co-operation on the part of the occupants of the buildings. It is not always convenient to make these surveys during the periods when offices in buildings and rooms in hotels are occupied and it is, therefore, necessary to adjust this work to the convenience of those occupying the buildings. While making surveys the inspectors are often called upon to answer questions brought up by individuals and, therefore, these men are cautioned as to what information they give out and at all times they must exercise tact throughout the period that they are assigned to the building.

Wiring Trace.—Surveys are also accomplished when necessary by means of a wiring trace. This trace is made by experts on wiring. From the point of entrance the service is traced to distribution location, feeders lettered A, B, C, et cetera, and traced to various panel boxes, where branch circuits are numbered. The circuits are then traced through and a complete record of the installation is made so that the control of all fixtures or individual lamps is known.

From the information thus obtained it is possible to determine the load carried on various feeders and branch circuits, and when necessary meters are installed to record the current consumption of any particular portion of the building. A record is then secured of the consumption of the premises operating as when investigated.

RECOMMENDATIONS.

Detailed surveys and wiring traces are used as a basis for making recommendations to effect a more economical or efficient lighting installation. When making recommendations of this kind, either one of two methods, or both, are followed.

In the first instance, where a change in lamp equipment only is necessary, a thorough investigation of the lamp situation is made. Temporary lamps are installed of the size recommended for use in the particular installation and left for a period long enough to permit of a decision being made. A quantity of lamps used in the installation are also tested to determine whether they are of proper wattage, voltage and efficiency. It is very often found that lamps of improper voltage are used, especially lamps lower than the voltage supplied to the building. This means a short and unsatisfactory life and frequent renewal of the lamps, which would not be necessary if proper voltage lamps were installed. The result of these tests very often show also that inferior lamps are being used, the efficiency not being entirely up to the latest standard. The cost of lamps is also investigated in order to see that a customer is operating under the most advantageous lamp contract as to quality of lamps and deliveries.

The second method is the substitution of new fixtures and lamps. Photometric tests are made of the installation as found. The suggested installation is then installed and tests are made for

TABLE II.—FORM USED TO SUBMIT RESULT OF FIXTURE TESTS.
Lighting and Wiring Report for the New York State Industrial Commission, 230 Fifth Avenue, New York City.

Type of fixture tested	Illumination test			Total lumens per Bay per fixture as tested	Wattage per fixture as tested	As tested length to top of dish	Diameter of dish	Report No.	Price per fixture F. O. B. 230 Fifth Ave. Not installed. No lamps	Sold by	Wiring system necessary for this equipment see plans
	Average measured per Bay	Per cent. utilization as measured	Equated to 5054 lumens ft.-candles								
Present system	1.14	—	—	—	Semi-indirect	30-in.	Lighting.	23528	—	—	—
# 1	4.12	43.7	5.80	3598	1-100 W.	30-in.	14-in. Adams	23530	\$6.50	The Fox Elec. Corp. 119 W. 42nd St., N. Y. C.	# 2
# 2	4.16	44.2	5.86	3598	1-100 W.	30-in.	14-in. Alberville	23531	6.50	Black & Boyd Mfg. Co. 17 E. 47th St., N. Y. C.	# 2
# 3	4.16	44.1	5.84	3613	1-100 W.	30-in.	14-in. Alba	23532	6.50	Macbeth Evans Glass Co. 143 Madison Ave., N. Y. C.	# 2
<i>Total Indirect Lighting.</i>											
# 4	5.10	38.5	5.10	5064	3-150 W.	30-in.	20-in. brass 3 separate reflectors	23533	38.50	Nat. X-Ray Reflector Co. 21 W. 46th St., N. Y. C.	# 1
# 5	—	—	—	—	—	—	20-in. egg shell white finish	—	30.25	Nat. X-Ray Reflector Co. 21 W. 46th St., N. Y. C.	# 1
# 6	4.71	35.3	4.69	5089	1-500 W.	30-in.	22½-in. white enamel	23534	9.00 30-in. from top of dish to ceiling	Black & Boyd Mfg. Co. 17 E. 47th St., N. Y. C.	# 1
<i>Special.</i>											
# 7	3.73	46.8	6.34	2978	1-200 W "C" Nitrogen	30-in.	16-in. metal reflector on top	23529	9.00	Black & Boyd Mfg. Co. 17 E. 47th St., N. Y. C.	# 1

When fixtures are ordered they should each be long enough so that the top of dish will come 30" from ceiling.

Lamps are not included in this schedule, as it is understood that they will be furnished by the Building Authorities.

The total cost for entire number of fixtures necessary has not been estimated, as no doubt the private offices will be equipped with a somewhat better type of fixture than desired for the general office. After the selection has been made from the list of fixtures, the total cost can easily be estimated. To this estimate the installation charge for fixtures should be added.

*The X-ray number 1073-F fixture has the same equipment as the 103-F with the exception that it is finished in egg-shell washable white which reduces the cost of the fixture somewhat. No test was made on this fixture, but the test on 103-F will hold good for this fixture.

In addition to the regular lighting fixtures to be ordered, would advise the installation of permanent exit fixtures equipped with 25-watt natural red lamps. These fixtures can be produced at approximately \$1.50 each (no lamp) from any one of the above concerns.

Fig. 5 shows the form in which the result of a test is submitted on different fixtures installed in a new building in order to decide the kind of fixtures and glassware which will be installed in the entire building.

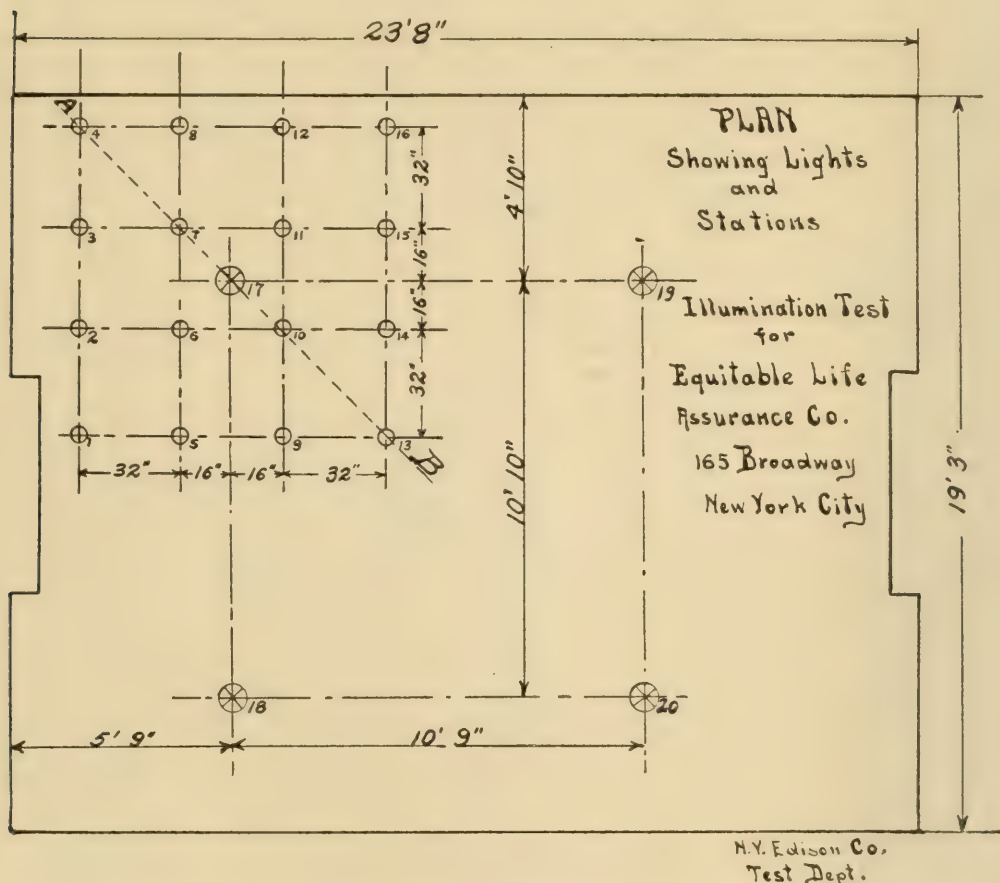


Fig. 2.—Form in which data on illumination tests are submitted.

All tests are conducted in typical portions of the building and the opinion of the company's representative usually carries weight because of his general knowledge of the subject and his impartial recommendation.

SUPERVISION.

The supervision of buildings plays a very prominent part in the reduction of current consumption. Records show that an actual saving, due to the supervision of the installation by inspectors familiar with the operation of the various classes of buildings, exclusive of changes, ranges from 10 per cent. in some classes of

buildings to 40 per cent. in others. When it is remembered that the lighting consumption of the building represents from 47 to 98 per cent. of the total consumption, the importance of this work can be realized. In many cases supervision covering 24 hours is desirable for a period of the time in order that some idea of the use of the installation may be had at all times. While it may seem unnecessary to maintain this 24-hour supervision, its importance may be realized by stating that in the large office buildings and

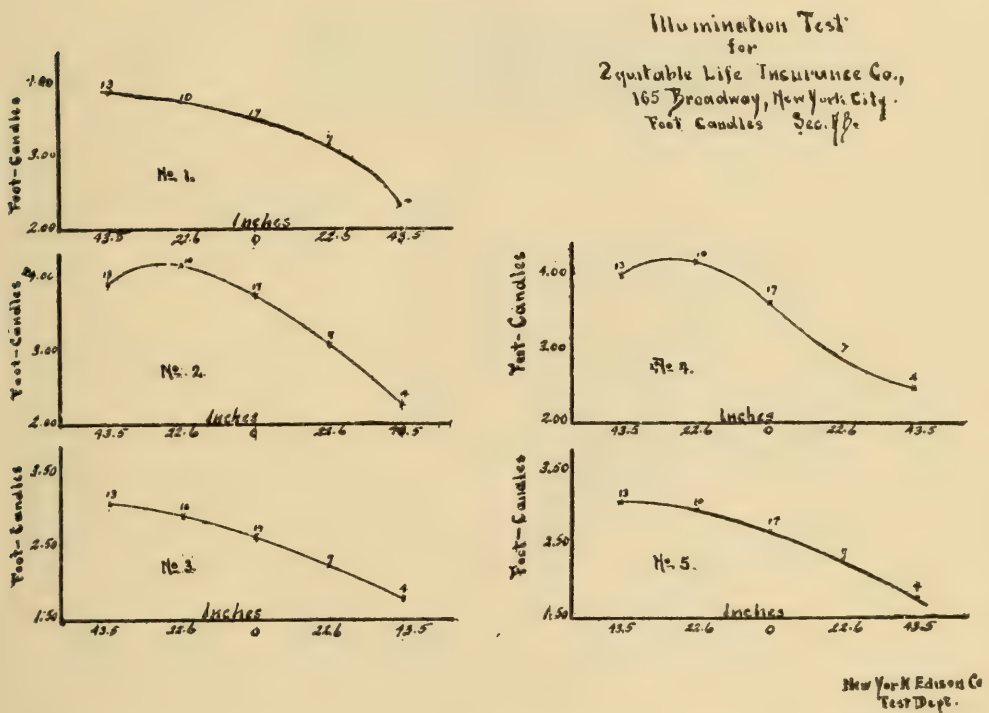


Fig. 3.—Form in which data on illumination tests are submitted.

factories, the cleaning is done after the usual working hours and it is necessary that the employees be instructed in the intelligent use of the lighting installation during this period as well as in the regular working hours of the day. In one installation the consumption for lighting between the hours of 6 P. M. and 8 A. M. represented 29 per cent. of the consumption for the total 24 hours. (Fig. 6.)

While this 24-hour supervision is being maintained, the men work in shifts of 8 hours each. These investigations are sometimes carried over a period of as long as 6 months or a year, in

order to collect sufficient data under all operating conditions during all seasons of the year. Usually a room in the office building, hotel or club is assigned to the representative from the company for his work, where the records of installation are kept during

35

Horizontal Illumination, 33" above floor.

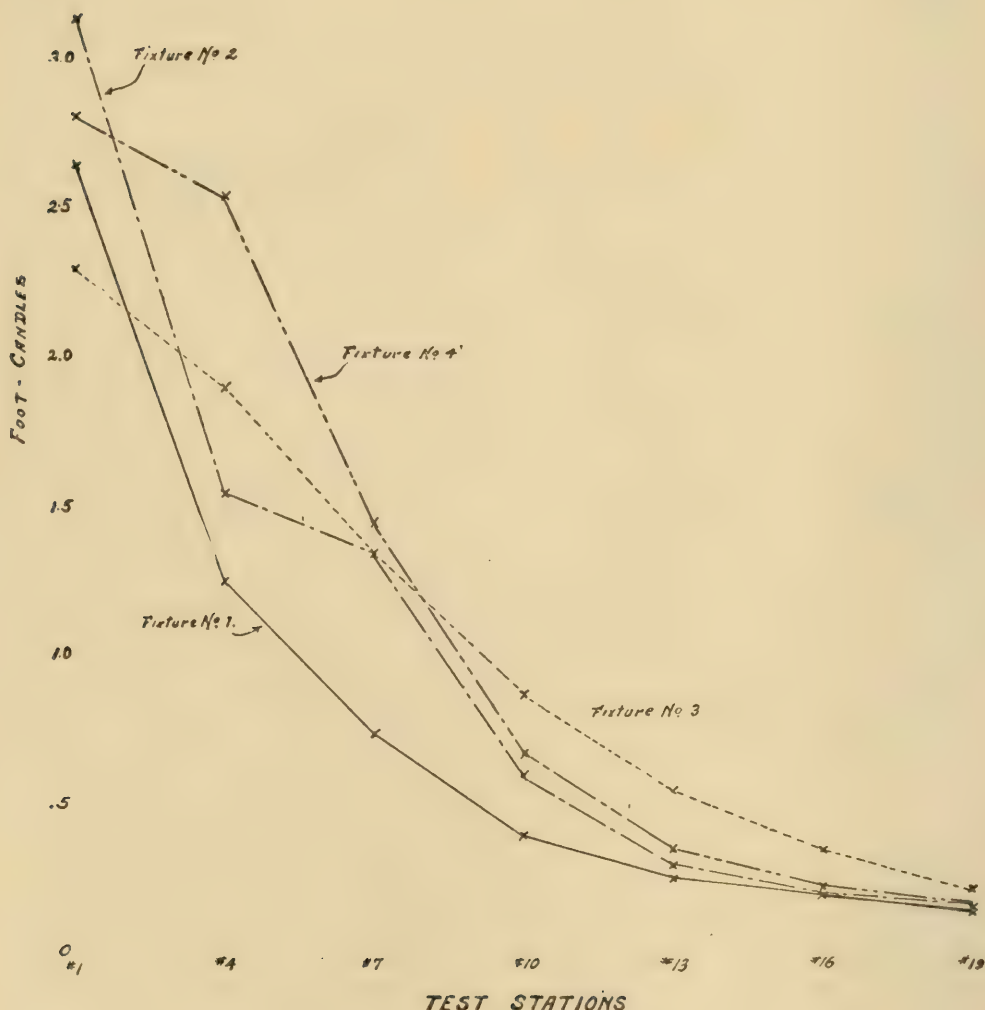


Fig. 4.—Form in which data on illumination tests are submitted.

the time when the patrol of the building is being made. Inspectors note and report any unusual use of the installation, or activities which tend to increase the consumption.

The saving which is effected is produced not only through the correction of the careless use of the installation but also by the

result of the moral effect produced upon the employees by an inspector being in the building at all times.

AVERAGE FOOT-CANDLES & CURRENT CONSUMPTION

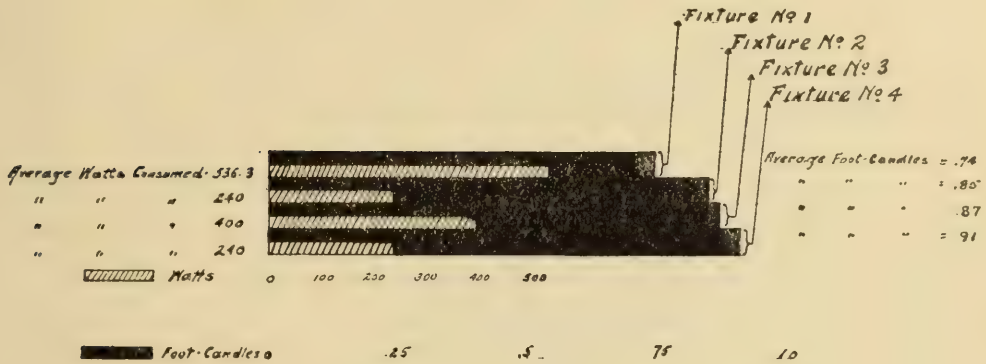


Fig. 5.—Foot-candle intensity compared with wattage.

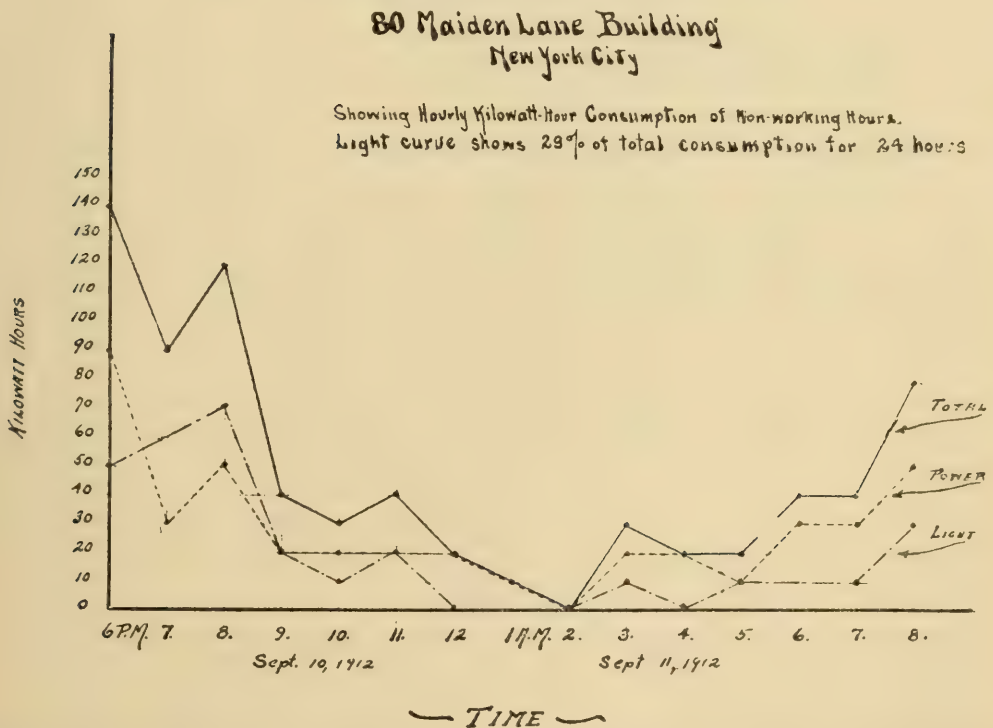


Fig. 6.—Curve showing hourly, kilowatt-hour consumption between hours of 6 p. m. and 8 a. m.

It is hard for one, not familiar with the operation of a system in a large office building for instance, to realize the extent to which lighting is misused. The question of waste by itself repre-

sents the major portion. Lamps burning when sunlight is streaming through a window, a whole floor or large percentage of a floor lighted when only a small section is needed, lamps left burning for hours after occupants of a building have left, constitute some of the forms of misuse.

Depreciation of the installation due to the lack of proper cleaning of the equipment has also a most pronounced bearing on the inefficient operation of a lighting system. After a number of investigations, particularly of office buildings, it was found that from 20 to 40 per cent. of the initial intensity has been lost due to dirt and dust settling on lamps and glassware, especially where indirect and semi-indirect systems are used. Added to this is the loss due to the blackening of the bulb after a good part of the life of the lamp has been spent, also dirt deposit on ceilings and walls. This per cent. varies of course depending upon the location of the building. This is not in any sense a criticism of the systems but the direct result of the lack of supervision on the part of building operators. It is encouraging, however, to see that this fault is being eliminated gradually by education through a better lighting propaganda.

These figures of depreciation may seem out of proportion to the results obtained on tests made in the past; nevertheless they are true. When conditions such as these are found and the installation is brought up to a state of efficiency, the psychological effect is marked. It rarely ever deteriorates again to the same extent.

Eye strain due to glare is another result of the misuse of a lighting system. Bright sources of light directly in front of clerks working steadily all day is a common occurrence. The ill effects produced can never be estimated. It causes dissatisfaction on the part of the clerk with his job, uneasiness and general discontent. Given as a reason, however, for these ailments, in most cases it is not given credence. Actual experience has demonstrated that in cases where the foot-candle intensity has been reduced from 20 with a bare lamp to 10 with properly diffused light, the bare lamp has been substituted again. This is a condition that can only be relieved by education and it becomes one of the responsibilities of the inspector having a building under supervision.

The company is often called upon to justify what seems to be excessive charges for current. Cases of this kind taken under supervision call for the keenest observation on the part of the inspector. Although recommendations can be made to reduce the consumption, the specific purpose is to determine the cause of the increase in the past. An instance might be cited to demonstrate the point.

A prominent concern occupying the greater portion of a twenty-story building requested an investigation. A survey was made immediately and compared with one made a few years previous. A decrease in the connected load was noticed due to the substitution of more efficient lamps and a change in fixtures. Despite this the increase had occurred. A 24-hour shift was maintained for the period of a month. Reports of the inspector showed that due to the increased business which had almost doubled, it was necessary to work the office force well into the night most every night of the week. Here was a case of ignorance on the part of the person responsible for the payment of the bills as to what was necessary to carry on the increased business. Evidence in the way of a check system on the number of men working each night and the number of hours use of the installation was all that was necessary to justify the charge. Without this supervision, this explanation might not have been as convincing.

In hotels and clubs the use of the installation differs considerably from the office and loft class of building. In the office buildings the greater portion of the consumption occurs in the daylight hours; in hotels and clubs the peak load comes between the hours of 7 and 10 P. M. In this latter class of buildings the careless use of light is always evident inasmuch as the rooms are most always occupied by transients who give little thought to the use of the installation. It is necessary, therefore, for maids and cleaners to make frequent visits to rooms in order to disconnect lamps that are usually left burning when the rooms are unoccupied. Regardless of this fact it has been found that the company's representatives can often find instances of wastefulness when making a supervision of the building.

In once case of a club, an efficiency man was employed at a salary of \$1,200 a year for the specific purpose of controlling the lighting installation, and records compared with previous years

showed that a saving was made in the bills equal to a good portion of the man's salary.

CURVE SHOWING
Effect of Cloudy Weather
on Consumption

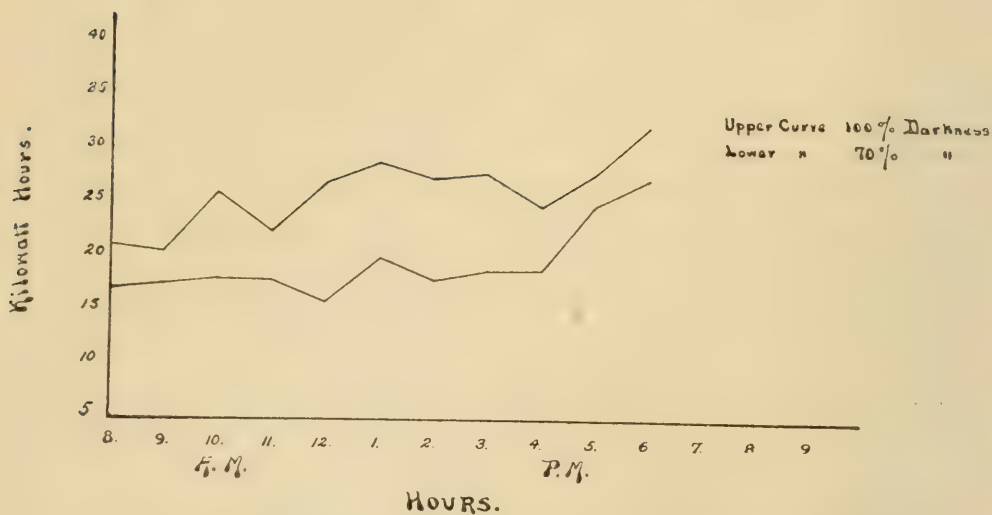


Fig. 7.—Curve showing effect of cloudy weather on consumption.

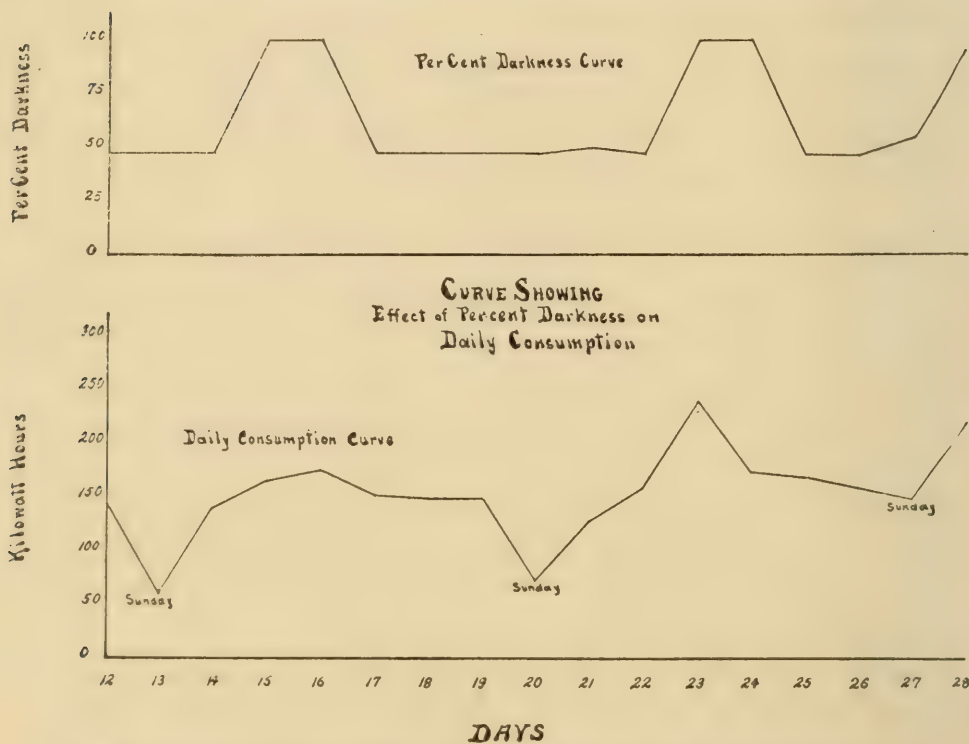
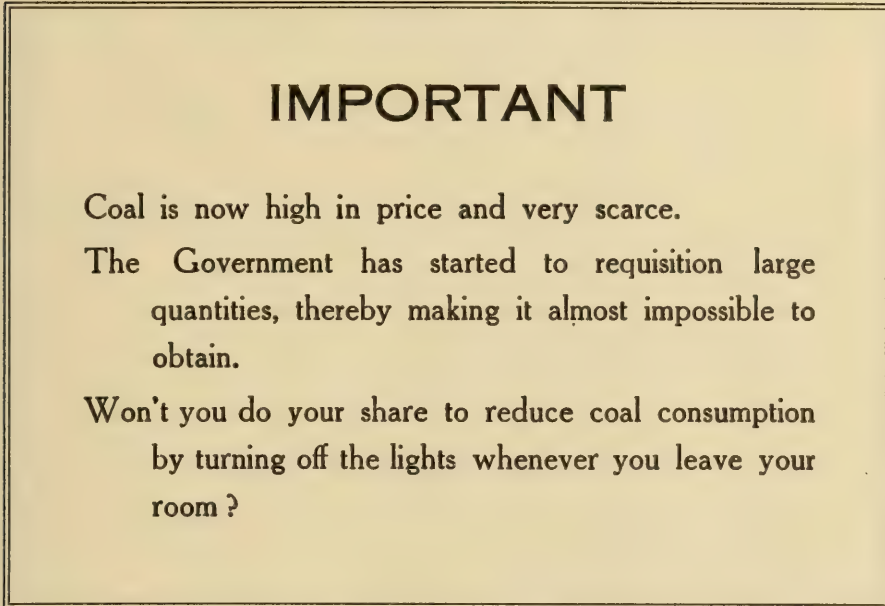


Fig. 8.—Curve showing effect of per cent. darkness on daily consumption.

As evidence of what can be done to impress upon the occupants of hotels the seriousness of waste that usually goes on, a sample card has been prepared which is posted about the hotel in prominent places.



Sample of card placed in hotels to effect lighting economies.

WEATHER CHARTS.

Weather conditions are carefully noted from day to day in order to check up any increased consumption. These charts are of considerable importance in checking up consumption with past months. (Figs. 7-8.)

CONCLUSION.

Importance of the economics of lighting, especially at these times, cannot be emphasized too much. By economy is not meant the elimination of any portion of the installation or the curtailment of its use but the intelligent application of light used efficiently and with good judgment.

DISCUSSION.

J. B. TAYLOR: I should like to ask Mr. Law to tell us how this record of darkness is kept. I understand that the Government Weather Bureaus have a recording machine which marks up once a minute whether the sun is out or whether it is cloudy. It seems to me that for work of this sort something very much more accurate than that would be in order. I know that they have gone to the extent of making a photometric measurement of the white surface right along through the day. I would like to know how that is done and if everybody goes to the pains of keeping a record of what the daylight illumination is along with spending so much time and money to determine what artificial illumination is. I do not think I have anything to say except to call attention to the fact that any business which is founded on sound principles does not have to persuade people to take what they do not want and they do not have to encourage people to do things in an economical way. It is rather striking I think for a representative of a lighting company to be explaining how conditions can be improved so that the product which they sell can be actually reduced. That apparently is what this is. Here is a company that is manufacturing and selling current and at the same time going out of its way, I presume you might put it that way, to see that that product, even though they get their money for it, is not called for and used in any greater amount than the economic conditions on broad lines call for.

S. B. BURROWS: It seems to me that there is a broad question in Mr. Law's paper insofar as the principles of business are concerned other than the detailed principles of illuminating engineering. However a central station should go into this class of work which Mr. Law has presented. If it is in line with war conditions I can see that we should go just as far as possible. I would like to know if Mr. Law believes that this service which is being rendered to the customers is as economical from the illuminating engineers' standpoint as it is from the central station standpoint of economy, insofar as business is concerned—I do not mean that in the narrow minded way of getting all you can. We know that the idea of the human being is to change all the time. I would like to know if Mr. Law believes that this same type of service should be rendered to every customer and to what extent.

G. H. STICKNEY: This paper is quite interesting as an indication of the importance which the New York Edison attaches to securing useful service for their customers.

Such lighting service depends in no small degree upon the proper application of lighting units. And while the modern units are more easily adapted than their predecessors, an inspection of installations in any city will reveal a large percentage of installations which are unnecessarily ineffective.

While the educational work of the Society and its members has advanced lighting practice very considerably, missionary work is still needed in order that the man who incidentally buys power and lamps, can realize a maximum value in illumination effect.

Not long ago a problem was referred to me, which illustrated the advantage of illuminating engineering experience in securing effective lighting results.

The problem involved the lighting for inspection purposes, of small glassy steel cylinders. After some experimentation the size of lamp had been increased until each operator was provided with a 100-watt clear Mazda lamp, and still they were unable to see satisfactorily.

The difficulty was that they had not realized that such surfaces give practically no diffuse reflection, and hence cannot be illuminated in the usual way.

By daylight the parts are observed by reflecting a portion of the sky. Likewise the artificial lighting should produce a miniature sky—or even diffuse light source which can be similarly reflected. When this principle was explained to the inspectors, 25-watt bowl frosted lamps with aluminum finished steel reflectors gave very satisfactory results. Not only was the quality and quantity of the work improved, but the eyes of the operators were conserved. Incidentally the cost of lighting was reduced.

In this last respect, this problem was exceptional, since on the average good illuminating engineering seems seldom to call for a reduction in lighting costs. True economy nearly always calls for higher expenditures than usually found in practice.

Too much emphasis cannot be laid on desirability to maintaining the intensity of illumination against slow depreciation from various causes. I believe that if we had available the value of the

light lost unnecessarily by dust accumulation, discolored surfaces and similar factors, we would be astounded by this magnitude.

MR. LAW: I will answer Mr. Taylor's question on how we prepare these charts. We get a daily report from the Weather Bureau and we put the charts in shape from that report. I do not know exactly how the figures are arrived at or on what they are based.

MR. TAYLOR: A bright sunny day with a cloud over it is reported as dark. There is no great difference between dark and light.

MR. LAW: We don't use any particular instruments to test the weather. However, the percentage of daylight in the summer time would be a good deal greater than in the winter.

F. H. MURPHY: In the particular phase of the work under discussion there is no doubt that two of the greatest enemies of economic operation are improper installation and improper maintenance.

The most serious phase of improper installation is the use of bare lamps usually so placed that they are directly within the line of vision. The introduction of the gas-filled lamp has materially increased the gravity of this crime, and it is to be hoped that nothing in this type of lamp smaller than the present 75-watt size will be placed upon the market. It is a question if even this size is not more of a detriment than a good to the lighting industry, for the price and size of this lamp appeals to the average layman as being within his reach. Added to this is the lure of a bright light and the encouragement of certain unscrupulous salesmen (more especially in the case of those handling a foreign type of lamp at a price a few cents under that of the standard lamp). The increased harm done to the eye is immeasurably greater than any saving in efficiency or improvement in color of light.

Not long ago I called at the house of a friend, a successful young business man, and was almost blinded when I entered the parlor. Their fixtures were the old style with sockets pointing outward at an angle of about 45° and equipped with clear bell-glass shades. They had been beguiled into purchasing some of the new 75-watt lamps and anticipated having an abundance of nice white light. It is unnecessary to describe the result. This is not an unusual case but rather one of frequent occurrence.

This particular illustration also brings up another phase of improper installation which is almost as serious and that is the use of mismatched lamps and reflectors. It is not an exceptional case at all to find a 250-watt bowl-frosted high efficiency incandescent lamp installed—not in but under—a 60-watt reflector. It is difficult to imagine anything more incongruous in appearance or unsatisfactory from the standpoint of illumination.

The work of educating the public is continually going on and there are many indications of progress, but there still remains an enormous amount of work to be done, and I believe that more emphasis than ever before should be given to the injurious effects to the eye of exposed high intensity light sources. The public cannot seem to realize the far reaching harm resulting from such sources of light.

The elementary principles of illumination should be taught in the schools and should begin with the grades. In the meantime it may be necessary to legislate against the promiscuous use of some of the high candlepower lamps except where properly equipped in order to reach a certain class of people who are so stubborn that they will not listen to reason or to their own judgment. I have in mind a certain corporation maintaining local stations about the city, who have installed very attractive places, keep their grounds in excellent shape and have very satisfactory lighting installations except for one feature. Their business is to cater to the automobile public and the manager of this section of the country who knows absolutely nothing about lighting and who will not listen to advice from anyone else, has determined that each of these establishments must maintain a 500-watt, high efficiency gas-filled tungsten lamp in clear glass globe and mounted about 7 ft. (2.1 m.) above the roadway. They get business of course because it is necessary to use what they have to sell, but a driver approaching one of the establishments does so in the face of a blinding light which is equal to that of a strong headlight, and no one can pass along the street without being blinded by it.

The matter of improper maintenance is principally a question of economy which calls for education only. We had until recently in our possession a lamp—one of the early types of tungsten lamps—which had an undisputed record of approximately

3000 hours' burning before its owner could be persuaded to part with it.

That the depreciation due to the collection of dust upon lamps and reflectors causes a very appreciable loss of light, there can be no question. Our tests tend to confirm the high values found by the authors of this paper. Depreciation due to collection of dust alone upon an installation in an office at the Oregon Agricultural College showed 25 per cent. in thirty days, and another set of tests at the same institution in a classroom in which blackboards were used showed a depreciation as high as 50 per cent. in thirty days. Certainly a regular and frequent maintenance of the lighting installation is justified by such results as these.

I would like to ask the authors what type of photometer they find most satisfactory for general measurement?

C. L. LAW: Tests are usually made for us by the Electrical Testing Laboratories and they use whatever photometer is best suited to the conditions. I understand that the Sharp-Millar photometer generally is used.

THE VISIBILITY OF RADIATION.*†

BY PRENTICE REEVES.

The theory of this subject has been given previously by Nutting¹ and Ives², and in those papers may be found a thorough treatment of the early literature. In this paper the writer wishes to present further data obtained by a method similar to that used by the above writers but using a different apparatus. The writer has data from thirteen subjects, five of whom were also used as observers by Nutting in his list of twenty-one subjects. The values for the spectral energy distribution of acetylene were those offered by Nutting and were obtained by weighting the data accessible up to that time as well as his own results in this laboratory. By using these values the writer was able to directly compare results with those of the other writers, and by using the values offered by Coblentz³ and revised by Coblentz and Emerson⁴ we can see the effect of various values for the spectral energy distribution of acetylene. The variations in the acetylene values are probably due to the different kinds of burners used, as Coblentz has shown that the spectral energy distribution in the longer wave-lengths is affected by the thickness of the radiating layer of incandescent particles in the flame.

The apparatus represented in Fig. 1 is a modification of the Nutting monochromatic colorimeter⁵ as manufactured by Adam Hilger of London. This type of apparatus has been described by Jones⁶ but the modifications made for its use in this experiment

*A paper prepared for the 1916-17 Correspondence Convention of the Illuminating Engineering Society, and circulated among members of the Society and others who were thought to be interested.

†(Communication No. 55 from the Research Laboratory of the Eastman Kodak Company.)

¹ P. G. Nutting, *Phil Mag.*, 1915, Vol. 29, p. 301; *TRANS. I. E. S.*, 1914, Vol. 9, p. 633.

² H. E. Ives, *Phil. Mag.*, 1912, Vol. 24, p. 149.

³ W. W. Coblentz, *Bull. Bur. Stds.*, 1911, Vol. 7, p. 243; reprinted 1912, Vol. 9, p. 109.

⁴ W. W. Coblentz and W. B. Emerson, *Bull. Bur. Stds.*, 1916, Vol. 13, p. 1.

⁵ P. G. Nutting, *Bull. Bur. Stds.*, 1913, Vol. 9, p. 1; *Zsch. f. Instkond.*, 1913, Vol. 33, p. 20.

⁶ L. A. Jones, *Phys. Rev.*, 1914, Vol. 4, p. 454; *TRANS. I. E. S.*, 1914, Vol. 9, p. 687.

TABLE I.—INDIVIDUAL VISIBILITY RESULTS.

Subject	λ .49	0.50	0.51	0.52	0.53	0.54	0.55	0.56	0.57	0.58	0.59	0.60	0.61	0.62	0.63	0.64	λ max.
J. B.	0.173	0.253	0.512	0.740	0.875	1.006	1.036	0.986	0.894	0.803	0.666	0.536	0.406	0.269	0.156	0.110	0.550
F. A. E. ...	0.189	0.382	0.553	0.712	0.799	0.880	0.946	0.955	0.898	0.799	0.662	0.558	0.395	0.287	0.196	0.116	0.555
M. F. F. ..	0.199	0.303	0.471	0.706	0.907	0.996	1.018	1.005	0.907	0.778	0.626	0.502	0.360	0.261	0.152	0.101	0.552
M. B. H. ..	0.151	0.212	0.381	0.674	0.840	0.936	0.990	1.003	0.891	0.786	0.681	0.577	0.464	0.354	0.225	0.159	0.556
K. H.	0.153	0.303	0.466	0.671	0.808	0.920	0.990	0.985	0.941	0.862	0.722	0.551	0.395	0.284	0.200	0.135	0.554
L. A. J. ...	0.206	0.330	0.491	0.749	0.864	0.965	1.001	0.982	0.882	0.764	0.622	0.518	0.391	0.276	0.188	0.105	0.554
C. E. K. M.	0.145	0.268	0.474	0.773	0.913	1.021	1.038	0.962	0.846	0.723	0.607	0.505	0.388	0.283	0.192	0.117	0.547
P. G. N. ..	0.236	0.318	0.467	0.716	0.861	0.984	0.996	0.986	0.891	0.785	0.554	0.519	0.388	0.282	0.190	0.120	0.555
P. R.	0.118	0.209	0.392	0.594	0.748	0.867	0.936	0.936	0.890	0.841	0.775	0.667	0.494	0.354	0.242	0.155	0.555
F. E. R. ..	0.216	0.334	0.503	0.726	0.862	0.950	1.011	1.007	0.931	0.884	0.652	0.496	0.361	0.243	0.141	0.095	0.553
R. G. S. ...	0.153	0.254	0.406	0.616	0.749	0.875	0.935	0.958	0.935	0.869	0.766	0.626	0.474	0.343	0.239	0.161	0.560
A. F. W. ...	0.187	0.321	0.580	0.750	0.857	0.970	0.994	0.970	0.882	0.783	0.650	0.501	0.374	0.271	0.193	0.136	0.552
R. B. W. ...	0.151	0.274	0.485	0.701	0.865	0.976	0.980	0.957	0.887	0.813	0.700	0.571	0.427	0.306	0.211	0.138	0.548
Average	0.175	0.289	0.475	0.702	0.842	0.950	0.990	0.977	0.898	0.807	0.676	0.548	0.409	0.293	0.194	0.127	0.553

warrant a separate description in this paper. The light from an acetylene burner⁷, S_2 , is focused on the slit, O_1 , by the lens L . The pressure of the gas was kept constant at 9 cm. as indicated on a water manometer, and the width of O_1 was determined by a series of preliminary experiments. A pair of nicol prisms, N , controlled the intensity of light from S_2 and by means of the

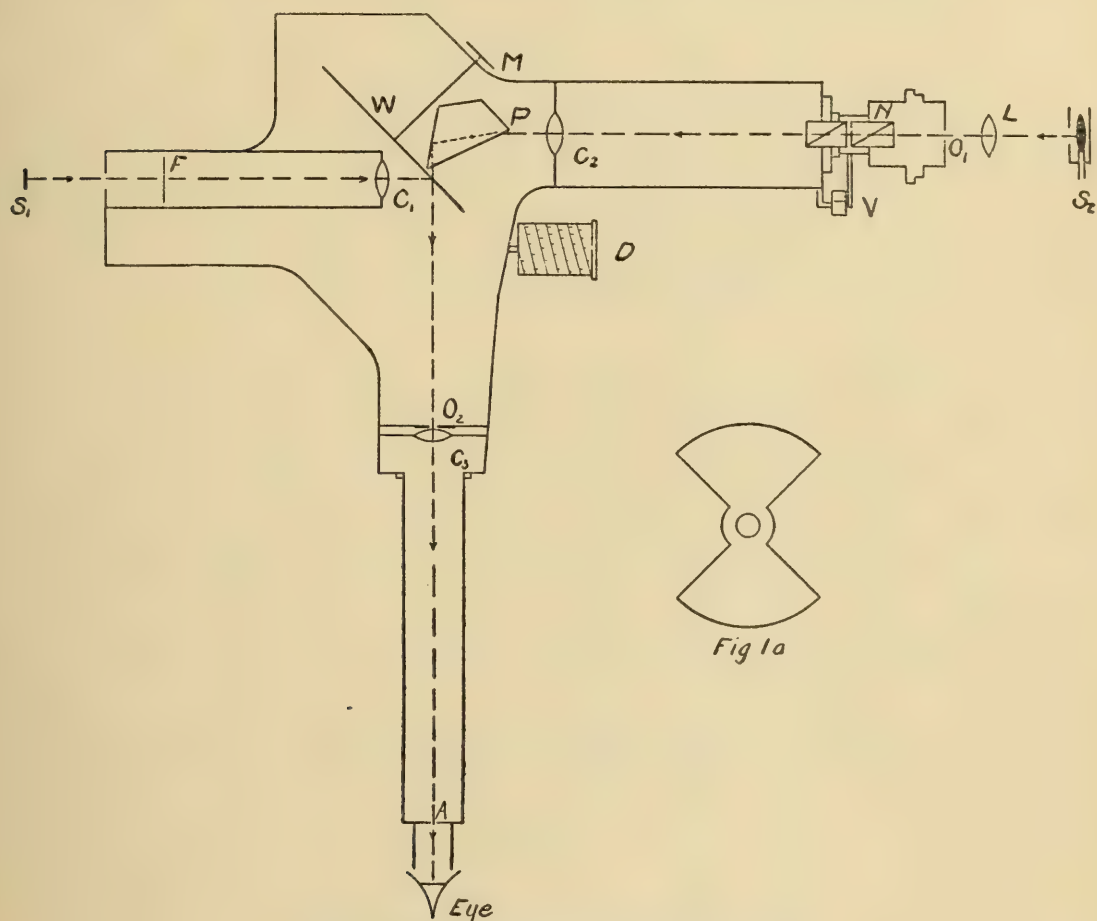


Fig. 1.—Modification of Nutting colorimeter.

vernier, V , and a graduated quadrant attached to the movable nicol we are able to determine the ratio of the incident to the transmitted intensities. C_2 is a collimating lens, P , a constant deviation dispersing prism operated by a screw carrying a wavelength drum, D , which indicates directly the quality of the light through this part of the system. S_1 is a gas-filled tungsten lamp the light from which passes through a daylight filter, F , and by

⁷ L. A. Jones, TRANS. I. E. S., 1914, Vol. 9, p. 716.

means of the collimating lens, C_1 , strikes the mat surface on the Whitman disk W . This disk, shown in Fig. 1a, is rotated by a motor belted to M and turns so that at one instant a reflecting quadrant sends a beam of standard white light from S_1 to the eye and the next instant a blank quadrant allows the colored light through P to reach the eye. The eye sees the light image at O_2 , which is screened down so as to restrict vision to the fovea and an artificial pupil, A , was used.

The white light source, S_1 , was regulated so as to give an illumination of 13 foot-candles at W and was kept constant at this intensity by means of connections through a Wolff potentiometer and a sensitive galvanometer. With both light sources constant and three independent series taken on different days we may safely assume the resultant average curves to be representative of the observers.

A constant width of slit was used throughout. In order to determine the necessary slit width correction the wave-length interval corresponding to the width of the slit, as one edge of the image is moved across the field, was determined throughout the spectrum by sighting on certain lines of mercury, hydrogen and helium. The relative slit width for any wave-length thus determined multiplied by the corresponding acetylene emission gave the value of the relative energy.

When taking a series of observations the necessary preliminary adjustments were made, the movable nicol, N , Fig. 1, was set for maximum intensity and the balance was made by shifting the wave-length drum. For observations between wave-lengths 500 and 680 the balance was made by setting the drum and moving the nicol. An electric tachometer was belted to the motor and the speed could be changed by variable resistance. As all observers were familiar with the theory of the so-called "critical frequency" in flicker balances each observer regulated the speed but no record was kept of these values. The relative energy for a given wave-length and the sine square of the angle read at V gives us the relative energy for equivalent luminosity. The values for the three independent series are averaged and plotted for each individual's curve. From this average curve the visibility curve for that observer was obtained and the visibility curves were reduced

to equal areas by weighting the ordinates according to height in order to compare separate curves and obtain the average curve of the group. These results are shown in Table I, and Fig. 2 shows the mean curve as compared with the curves of other writers.

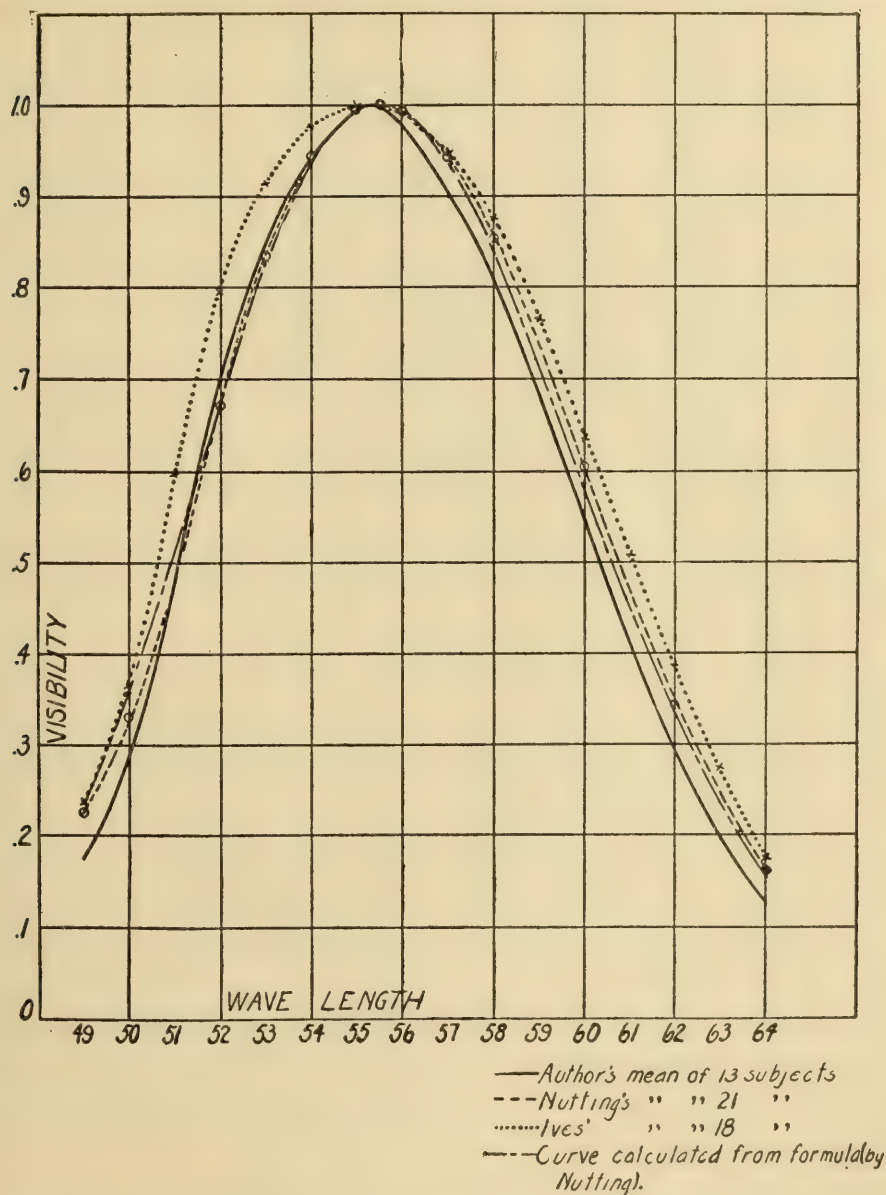


Fig. 2.—Visibility curves.

In Table II are shown the results obtained by using the different values for the acetylene emission and the mean from Nutting's and Ives' results as well as the results computed from the formula offered by Nutting. This formula was found to represent visi-

TABLE II.—COMPARATIVE VISIBILITY RESULTS.

Wave-length	Mean V from Table I.	Coblentz data publ. 1911	Coblentz data publ. 1916	Nutting's Mean	Ives' Mean	Computed from formula
0.49	0.175	0.172	0.172	0.227	0.235	0.232
0.50	0.289	0.283	0.275	0.330	0.363	0.358
0.51	0.475	0.471	0.474	0.477	0.596	0.514
0.52	0.702	0.705	0.686	0.671	0.794	0.675
0.53	0.842	0.851	0.841	0.835	0.912	0.824
0.54	0.950	0.947	0.935	0.944	0.977	0.933
0.55	0.990	0.988	0.993	0.995	1.000	0.994
0.56	0.977	0.982	0.985	0.993	0.990	0.993
0.57	0.898	0.926	0.935	0.944	0.948	0.939
0.58	0.807	0.825	0.836	0.851	0.875	0.839
0.59	0.676	0.693	0.710	0.735	0.763	0.717
0.60	0.548	0.552	0.580	0.605	0.635	0.585
0.61	0.409	0.417	0.446	0.468	0.509	0.456
0.62	0.293	0.294	0.319	0.342	0.387	0.343
0.63	0.194	0.185	0.214	0.247	0.272	0.235
0.64	0.127	0.125	0.140	0.163	0.175	0.158

bility very closely between the wave-length of 0.48 and 0.67 and is of the form

$$V = Vm R^a e^{a(1-R)}$$

where $R = \lambda_{\max.}/\lambda$ and $a = 181$. When the writer used Coblentz's revised data for acetylene the results agree remarkably well with these computed results.

In Table III the acetylene values used by the writer and Nutting are given as well as the two sets of values published by Coblentz. The greatest differences in these values occur in the region of the longer wave-lengths and as has been said are probably due to the different types of burners used. The spectral energy distribution of acetylene is probably better known than any other light source and the burner used in this experiment gives an extremely constant quality of light.⁸

In comparison with the other curves shown in Fig. 2 the writer's visibility curve for the thirteen subjects is slightly more contracted. The maximum visibility occurs at wave-length 0.553 in agreement with Ives' curve as against 0.555 for Nutting's curve.

⁸ Standardized burners may be obtained from the Research Laboratory, Eastman Kodak Company, Rochester, N. Y.

TABLE III.—SPECTRAL ENERGY DISTRIBUTION OF AN ACETYLENE FLAME.

Wave-length in μ	Nutting data	Coblentz old data	Coblentz new data
0.48	11.1	16.5	17.0
0.50	14.4	21.7	21.9
0.52	18.4	27.6	27.9
0.54	23.2	34.8	35.0
0.55	26.1	—	38.9
0.56	29.1	43.7	42.9
0.58	36.2	54.0	52.2
0.60	44.2	66.3	62.1
0.62	53.7	80.5	73.0
0.64	63.8	96.5	84.7
0.66	74.6	112.8	97.4
0.68	86.1	130.1	110.9
0.70	98.2	147.0	124.6

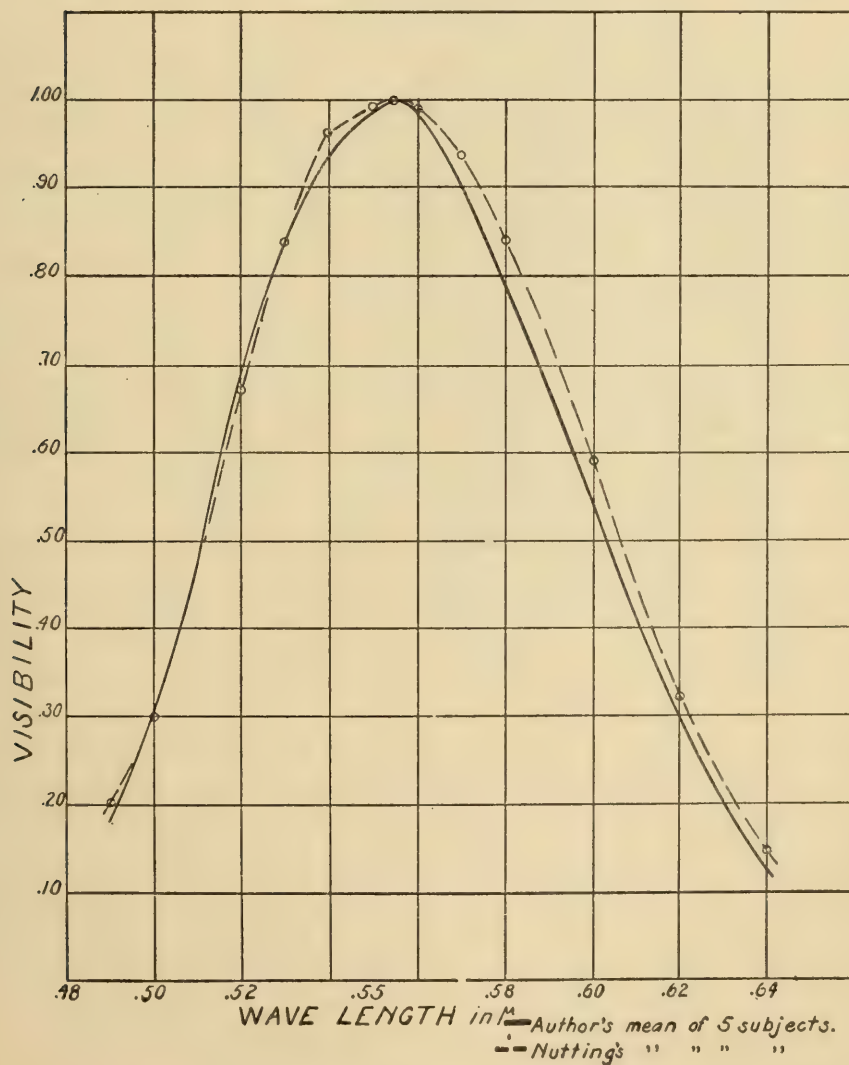


Fig. 3.—Mean of author's results and Nutting's results.

Fig. 3 shows the mean of the writer's results and Nutting's results on the five subjects who served as observers in both experiments. The average maximum visibility found by the writer is 0.555 and by Nutting 0.554.

This work was carried out at the suggestion of Dr. P. G. Nutting and the writer wishes to thank him and the other members of the laboratory for their assistance.

AUTHOR'S NOTE.—This paper had been completed before a paper by Coblentz and Emerson† appeared so that their data have not been included.

DISCUSSION.

W. W. COBLENTZ: Some time ago Ives and Kingsbury showed that the visibility curves published by Ives, and by Nutting do not fulfil the requirements of physical photometry; that the visibility curves are not high enough in the red. They determined experimentally the visibility curve (luminosity solution) which must be used in a physical photometer in order to give the same results as they obtained with a visual photometer.

The visibility data of Coblentz and Emerson happily coincide closely with the curve predicted by Ives and Kingsbury; especially in the red end of the spectrum where the older visibility data are most in doubt. The visibility data of Nutting (and of Reeves who agrees closely with Nutting) agree with those obtained by Coblentz and Emerson if reduced on the basis of the spectral energy measurements made by the latter, and hence fulfil the requirements of physical photometry. (See Sci. Papers Nos. 279 and 303 of the Bureau of Standards.)

PRENTICE REEVES: As a result of recent communication and conversation with Dr. Coblentz the statement that "the variations in the acetylene values *are probably* due to different kinds of burners used.," should be made to read "*are* due to different kinds of burners used.". In the recent paper by Coblentz and Emerson more detailed consideration of the relative color sensitiveness of the observers was taken and with a larger number

†Coblentz, W. W., Emerson, W. B. Relative sensibility of the average eye to light of different colors and some practical applications of radiation problems. Scientific Paper 303 Bureau of Standards, issued Sept. 12, 1917.

of observers individual variations are not so effective on the general overage, with fewer observers the presence of one or two blue sensitive observers, for example, will materially effect the shape of the average curve.

My comparison of the various data obtained by the different writers should be used with the knowledge of the difficulties of comparing results from the different types of burners. The later data on acetylene given by Coblentz should wholly replace the earlier data.

At present I heartily agree with Dr. Coblentz on the necessity of reducing the data obtained by Dr. Nutting and by me.

TRANSACTIONS OF THE Illuminating Engineering Society PART II -- PAPERS

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No. 2

LIGHTING CURTAILMENT.*

BY PRESTON S. MILLAR.

Synopsis: The coal used in the production of electric light is less than 2 per cent. of the total coal output of the country. Curtailment of lighting can therefore accomplish relatively little as a coal saving measure. Standards of illumination intensity before the war were in general too low. In view of the war and the fuel shortage, lighting ought to be reduced in some classes of service and increased in others. Any practicable curtailment is about 3 per cent., which means about 360,000 tons of coal per annum, or a trifle more than five one-hundredths of 1 per cent. It is practicable to effect much larger savings by other methods with less disadvantage to the public.

The most important thing is to win the war. The need for directing money, energies and materials toward the prosecution of the war makes it imperative that waste and extravagance be eliminated. Economy, in lighting as in other things, contributes to victory.

Economy involves adjustment of resources to secure the best results. As Ruskin has said, "Economy no more means saving money than it means spending money." Economy in lighting in the present circumstances depends upon:

1. Securing best accomplishment of the results which the lighting is intended to bring about, subject to the need for

* This paper was presented at a special meeting of the Illuminating Engineering Society in New York on February 14, 1918, and at a meeting of the Philadelphia Section on February 15, 1918.

2. Reducing consumption of fuel by the elimination of unnecessary lighting and by reduction of other lighting so far as the emergency warrants. Emergency reduction should be undertaken after due consideration of
 - (a) the amount of fuel saving which can be accomplished,
 - (b) the disadvantages involved in the reduction, and
 - (c) the practicability of saving the same amount of fuel otherwise with less disadvantage.

THE PLACE OF ILLUMINATION IN OUR AFFAIRS.

Artificial light makes possible practically all the nocturnal activities which go so far toward differentiating modern from ancient life. It facilitates and renders safe a wide range of industrial, educational and recreational activities which are of inestimable material and spiritual benefit to the country. A moment's contemplation of the curtailment of living which would ensue if there were no artificial light will convince of its invaluable and indispensable nature.

THE COST OF ILLUMINATION.

The cost of artificial illumination of all kinds is $\frac{1}{2}$ to 2 per cent. of the total expenditure of the people. It compares with certain other expenditures as follows:

Illumination	\$500,000,000 ¹
Liquors	665,000,000 ²
Tobacco	490,000,000 ³

The great value of artificial light to the public, and its small cost, are important considerations which ought not to be neglected when discussing lighting curtailment.

COAL CONSUMED IN ELECTRIC LIGHTING.

The significant figures to have in mind when discussing this subject are as follows, all being rough approximations:

APPROXIMATE COAL CONSUMPTION FOR 1917.

Total coal output of the country.....	640,000,000 tons ⁴
Total employed in production of electric light and power (traction excluded)	45,000,000 tons ⁵
Total employed for production of light by electricity (see note)	12,000,000 tons ⁶



Total Coal-1917



Total Coal-
Electric Light



Total Coal-Electric
Light and Power

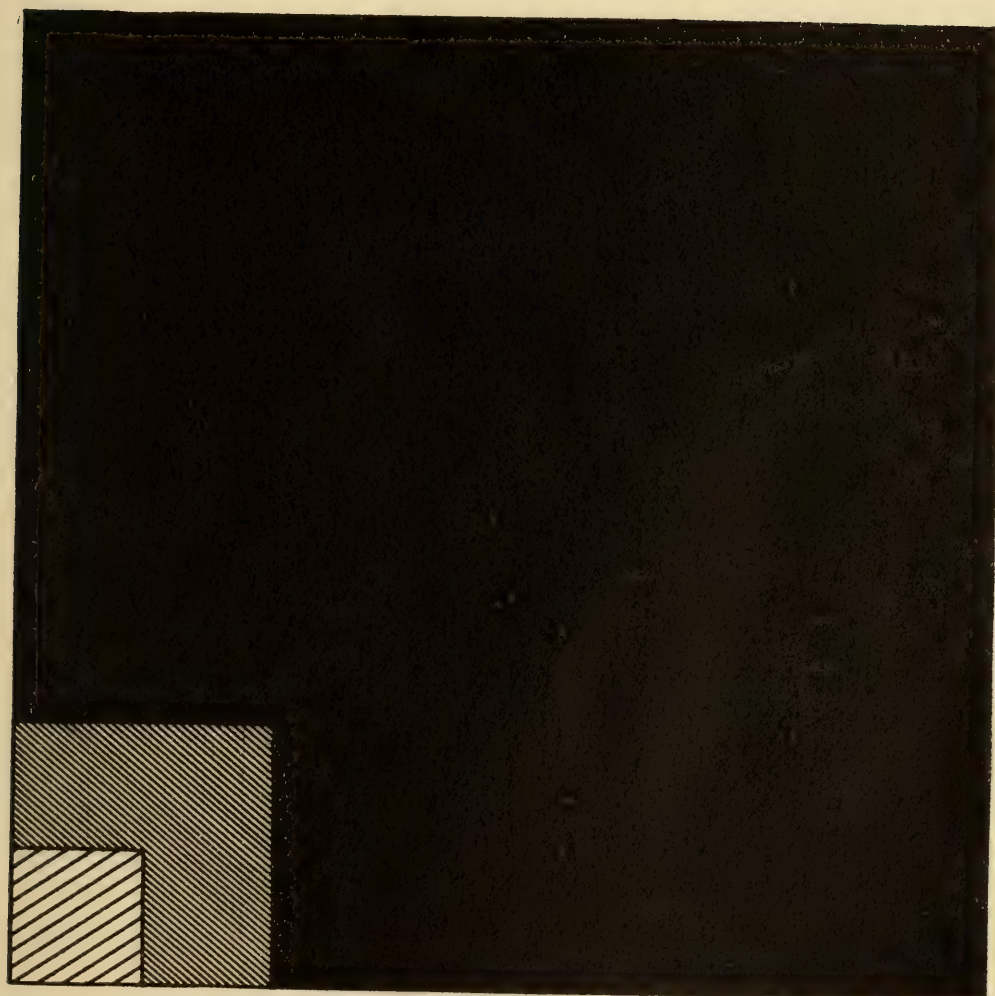


Fig. 1.—Coal consumption of the country.

Fig. 1 is a representation of these quantities, which may assist in indicating relative magnitudes.

According to these estimates, about 2 per cent. of the coal consumption of the country goes into electric light. We are told that our consumption of coal must be reduced by 50,000,000 tons per annum.⁷ If the entire electric lighting of the country were cut off the saving in coal would be only 24 per cent. of the required saving. In considering lighting curtailment therefore, it is important to bear in mind that even if every candlepower of electric lighting were wasted the loss of coal involved would not be the great outstanding coal waste of which this country is guilty. As relatively little light is wasted, it is evident that the amount of coal which can be saved by curtailment of electric lighting is small. Our discussion has to do with the saving which it may be possible to effect in the 2 per cent. of the country's coal which is consumed in electric lighting.

PRESENT STATUS OF ARTIFICIAL LIGHTING.

Before the present period of fuel stringency, the employment of artificial light had increased rapidly. In some classes of service it had attained a stage which in the present state of the art was considered by experts to be reasonably satisfactory with respect to intensity though not so in respect to the manner in which the light was used. Such a condition, however, was exceptional. Upon the whole artificial lighting has been inadequate, considering the best advantages to the public. Safety, conservation of vision, economy in production, commercial success, and esthetics, singly and in various combinations, require improved utilization of artificial light which in many, if not in most cases involves the production of more light.

Within the past two weeks the author has requested a number of members of the Society to express their views as to the ade-

NOTE:—*Coal Data in this paper Confined to Electric Lighting.*

Properly a paper of this kind presented before the Illuminating Engineering Society ought to include all forms of light. Practically, however, the time available for the preparation of this paper has been so short, that it has been necessary to confine attention to electric lighting. The principles which are emphasized apply equally as well to flame illuminants. The manner of their application, the conditions of use which affect and even govern their application, and the conclusions to be drawn are peculiar to each kind of lighting.

quacy of standards of lighting practice. The consensus of the opinions secured¹⁰ is presented in the following table:

Classes of lighting service	Present day ideas of desirable practice as compared with practice just before the war, per cent.
Street (civic, not white way).....	+ 70
Public buildings (schools, colleges, institutions, etc.).....	+100
Industrial	+175
Protective (outside and inside).....	+400
Commercial (offices, stores, etc.).....	+ 40
Residence (including hotels, clubs, etc.).....	+ 30
Recreational (churches, theatres, saloons, etc.)....	0
Advertising (signs, white way, show windows, etc.).....	0
Miscellaneous	+100

Assuming a certain distribution of illumination among the several classes of lighting service named¹⁴ (see page 126) it develops that according to the consensus of opinion of these thirteen men, electric lighting as a whole ought to be increased by about 72 per cent. in order to conform to the consensus of their opinions as to desirable intensities.

In relatively few instances has more artificial light been employed than the circumstances warrant. There is occasionally encountered a popular opinion that artificial light is used more largely than is necessary. The phrase "over illumination" appears to have found some place in popular parlance. The origin of this impression is to be found not in the use of too much artificial light, but rather in the glare of exposed light sources which are excessively bright and which create the impression of high illumination. Good illumination involves correct practice in respect to intensity, diffusion, direction, and color of light. When the artificial illumination is correctly designed as to diffusion and direction, there is no suggestion of over illumination. To talk of over illumination by artificial light is unreasonable, in view of the fact that intensities range from, say, a minimum of 0.01 foot-candle outdoors to a maximum of 5 foot-candles indoors, while sunlight as we employ it ranges from, say, 10 foot-candles indoors to a number of thousands of foot-candles outdoors. How then is it possible to speak of over illumination by artificial light, when the brightest artificial illumination is only, say, one-quarter of the least bright sunlight which is used for the same purpose within buildings?

Let us base our consideration firmly upon the fact that indiscriminate curtailment would involve reduction from lighting standards which are less than adequate.

WASTE VERSUS EXCESS.

There is an important distinction between waste and excess in lighting. Waste has no compensations; it should be eliminated wherever found. Lamps left burning when no light is needed; unconsumed fuel in discarded ashes; unconsumed gases passing up the chimney—these are wastes.

Excess, on the other hand, is difficult to define, and there is always room for difference of opinion as to the line of demarcation between sufficiency and excess. Illumination which would have been considered excessive a few years ago is now accepted quite as a matter of course. This is not a question of style—activities are now more intensified. Speeding up all along the line is associated with higher levels of illumination, either as cause or effect. Therefore while we should condemn waste wherever it is found, “excess” should be examined carefully before a verdict is reached, lest more be lost than gained as a result of reduction below intensities mistakenly regarded as excessive.

OBJECTS OF CURTAILMENT.

The objects to attain which lighting may be curtailed justifiably are principally:

Military advantage.

Release of generating capacity for more important work.

Coal saving.

Money saving.

Beneficial psychological effect.

Military Advantage.—In England and France lighting has been suppressed with a view to concealing cities and landmarks from enemy aviators. Thus far this phase of the problem has not influenced practice in this country. Lighting restrictions have served no direct military advantage.

Release of Generating Capacity.—Where there is a shortage of generating capacity, as has occurred in a few localities, the removal of the non-essential load for the purpose of releasing

generating capacity for work contributing directly to the prosecution of the war and to the important needs of the public, is a valuable expedient. "Unnecessary"* lighting falls within this class.

Coal Saving.—A saving of coal which is not justifiable because uneconomical in ordinary times becomes entirely so when the supply is inadequate. Curtailment of "non-essentials," including unnecessary lighting, is in order. At such a time it is desirable to do this if the advantage of coal saved outweighs the disadvantage of curtailment.

Money Saving.—The value of artificial lighting is incommensurately greater than its cost to the public, and it is used rather too sparingly. From this point of view alone, more money ought to be spent on artificial lighting. A thrift campaign will touch many non-essentials and some essentials before general curtailment of artificial lighting becomes desirable on this score. Real economy, generally speaking, is not to be served by a reduction in artificial lighting.

"Psychological Effect."—The "psychological effect" which is said to be desirable may be any one of the following: it may remind people of the need for reducing light at home; it may remind people that we are at war and that economy is to be practiced in all directions; it may create the impression that large savings in coal are being effected.

The same qualities of artificial lighting which render it conspicuously successful as an advertising medium bring about attempts to curtail it with a view to advertising to the public the need for reduction of consumption of other commodities. Whether or not the effect upon the public of curtailment of advertising lighting is that which some people have anticipated is a question. If the "psychological effect" of extinguishing prominent electric signs prompts the public to save in coal as in other things, the result should be good. If it leads the public to believe that large coal savings are being accomplished through such curtailment, the result is not likely to be good. For best ultimate results our actions must be based upon facts and not

* Necessity and luxury are relative terms. Lighting which is important may be dispensed with in a national emergency. That which seems least important is here classed as "unnecessary."

upon erroneous impressions. In either event the "psychological effect" will be felt most strongly at the start, and will cease to operate conspicuously after the public shall have become accustomed to the new order of things.

METHODS OF LIGHTING CURTAILMENT.

Various methods of reducing artificial lighting as a war measure have been proposed as follows:

1. Remove unnecessary lamps.
2. Extinguish all lamps when they are not needed.
3. Extinguish some of the lamps when possible.
4. Substitute smaller sizes of lamps.
5. Replace inefficient by efficient lamps.

Remove Unnecessary Lamps.—This should be done by all means. The power, the labor of attendants and the lamps themselves are needed elsewhere for important work.

Extinguish All Lamps When They are Not Needed.—There is every reason for emphasizing the desirability of eliminating unnecessary use of light. Fuel administrators and lighting companies have urged this expedient very prominently. Bulletin V of the Committee on Coal Conservation of the Chamber of Commerce of the United States, entitled "Conservation in Use of Coal" (see Appendix) contains some excellent suggestions for curtailment of lighting.

Extinguish Some of the Lamps When Possible.—To have available a complete lighting equipment with lighting units of reasonable power to meet the requirements in a given installation is an excellent thing. Some of these may be extinguished for certain purposes without disadvantage. Thus, in a home, a room which is needed for reading purposes at certain times, and is used at other times for purposes which do not require close application of the eyes, may be served by a reduced amount of illumination on the latter occasions. This plan is superior to that of replacing lamps of reasonable power with small lamps, making it impossible to get the full illumination when it is required.

Likewise, in small specialty shops, or in certain rooms of mercantile establishments, a part of the lighting system may be used

when customers are not present and the full lighting may be turned on when customers enter.

Substitute Smaller Sizes of Lamps.—This is advisable in a few classes of service where lighting is now of ample intensity. In general, or as a wholesale proposition, it is inadvisable for the following reasons:

Present intensities of illumination are less than in expert opinion are desirable for the most economical ultimate results.

There is now a lamp shortage, and to dispense with moderate sized lamps would result in the loss of many of them which would be a serious economic waste.

Smaller lamps are of slightly lower efficiency and are more fragile than are moderate sized lamps. Fragility means shorter life in service. The extent to which this is the case is indicated in the following table:

Lamp rating in watts	Relative candlepower produced per watt	Filament breakage in careful handling in laboratory after 1,000 hours of burning per cent.
100 (gas filled)	132	—
100 (vacuum)	107	0.4
75 (gas filled)	121	—
60 (vacuum)	102	0.4
50 (vacuum)	100	1.4
40 (vacuum)	99	1.4
25 (vacuum)	96	1.8
15 (vacuum)	90	3.7
10 (vacuum)	79	6.4

When using small lamps one is between the devil and the deep sea. If he cleans them in order to maintain them at the highest efficiency and avoid waste due to dirt, he is likely to break the fragile filaments. On the other hand, if to save the filaments he does not clean them, waste is incurred through dirt absorption. The moderate sized lamps which are used more generally are more rugged, and do not place the user in this awkward predicament.

Replace Inefficient by Efficient Lamps.—With few exceptions, carbon and Gem lamps and open gas-flame burners ought to be eliminated and replaced by the more efficient Mazda and gas mantle lamps respectively. For the same energy a Mazda lamp will produce three times as much light as a carbon lamp, and a

gas mantle lamp will produce five times as much light as an open-flame burner. The relatively inefficient carbon lamps and open-flame burners usually produce too little light for the purpose, and the full light of the more efficient illuminants which may be used to replace them is often desirable. Where it is not necessary, however, advantage may be taken of the substitution of the more efficient illuminants to reduce consumption below that of the carbon lamp or open-flame burner by using smaller size lamps of the efficient types.

OTHER MEANS OF SAVING FUEL.

To arrive at suggestions for saving fuel used for lighting purposes without deleterious effect, one should consider the elements of inefficiency in lighting, and the possibility of eliminating them. Such a line of consideration brings the following to the fore.

Good Utilization of Light.—Selection of suitable reflectors or other lighting accessories may in some cases make it possible to provide equally good illumination while using smaller or fewer lamps.

Good Maintenance.—Dirt cuts down lighting efficiency markedly. Statistics are available to show that cleaning of lamps and lighting accessories has increased the useful illumination by as much as one-third. It is reasonable to state that the difference between good and poor maintenance of a lighting system will account for 20 per cent. of the total light.

Use of Good Reflecting Surfaces.—Good white paint or other good light reflecting surfaces conserve light materially. Sometimes a wall or side of a building may be whitewashed with the result that more daylight is reflected into an interior, thus reducing the use of artificial light.

Other measures which are attracting favorable consideration, but which are not within the scope of illuminating engineering, include the following:

Daylight Saving.—The adoption of summer daylight saving as now proposed is estimated to be capable of reducing the coal consumption of electric central station steam plants by 230,000 tons per annum for the entire country.¹⁵ A suggestion to advance

the period of activity by one hour the entire year round, which is now attracting considerable attention, is estimated to afford about the same saving to the public in lighting bills, but to result in a somewhat greater saving of coal on account of the more favorable load factor for power plants which would result in the winter months.

Utilization of Water Power.—It is estimated that only about one-tenth of the available water power of this country is developed. Most of the remainder is in the western states. Much of it is remote from centers of population. All will require time for development after legislative impediments shall be removed. It is clear, however, that tremendous reductions in coal consumption may be effected in the future through further utilization of our water power resources.

Elimination of Small Power Plants.—The inherently lower efficiency of small plants, together with the less expert operation which in general they receive, is estimated to be responsible for the use of one-third more coal than necessary. This element of waste is even more serious in England than in this country, as is evidenced by a recent report (April 16, 1917) of the Coal Conservation Sub-Committee of the Reconstruction Committee,¹⁸ in which, after pointing out that the average capacity of English generating plants is 5,000 horsepower, it is stated that "The present coal consumption if used economically would produce at least three times the present amount of power."

DESIRABLE ADJUSTMENTS OF LIGHTING.

The extent to which it is desirable to reduce artificial lighting depends upon the seriousness of the emergency which is to be met. The grave shortage of coal during the past few weeks has made necessary the reduction of a number of luxuries and some necessities. Artificial lighting has borne its full share of the necessary curtailment, and rather more than its full share of the attention of the public in general as a means of compensating for the fuel shortage.

The extent to which lighting should be adjusted in the present unusual circumstances will perhaps be better appreciated if artificial lighting is considered separately for the various principal kinds of service, which for the present purpose are classified as,

street lighting, the lighting of public buildings, industrial lighting, protective lighting, commercial lighting, residence lighting, recreational lighting and advertising lighting. Adjustments may be effected in each class by altering the level of illumination intensities maintained, or by changing the extent of the lighting.

Street Lighting.—It is desired to differentiate between civic street lighting considered under this head, and display lighting for business purposes, sometimes called “white way” lighting. Civic street lighting provides safety against collisions, protection against criminals, reduces the amount of policing necessary on the streets and permits the public to go about after dark conveniently and without annoyance. It costs the public about \$1.00 per capita per year. It is generally adjusted as to intensity with respect to extent of the traffic and the real estate development of the neighborhood. The development of the automobile has created a need for much more light in the streets in order to provide for safety against collision and crime. It is generally considered that the lighting of streets is inadequate. Of the total mileage of lighted streets only an insignificant proportion is lighted to such an extent as to make it advisable to curtail the lighting even in times of fuel shortage such as we are experiencing.

Abroad during 1915-16 extreme precautions were taken in the way of eliminating or concealing from above all street lamps. It developed, however, that the menace to the public from street accidents was much more serious than the menace from enemy airships.*

It is stated that from Aug. 1, 1914, to Jan. 31, 1915, in the metropolitan area of London during the hours of darkness 954 persons were killed in street accidents, and 137 were killed in airship raids. To the reduced street lighting is attributed a large part of the excess of street accidents. English technical literature makes it evident that during the past year official and

* The following is the record of motor vehicle accidents in the city of London:¹⁶

Year	Number of accidents	
	Fatal	Non-fatal
1913	424	13,157
1914	493	14,638
1915	666	16,366
1916 to Oct. 31	509	11,827

public opinion has undergone considerable change on this question. Public lighting restrictions are less severe, and the former street lighting is being restored to some extent.

Street lighting should not be considered independently of sign lighting. In localities where the public congregates in large numbers at night, there are likely to be electric signs which add very materially to the street illumination. The extinction of these signs places entire dependence upon the street lighting system which alone sometimes proves inadequate. In certain portions of Times Square, New York City, not in the vicinity of any particular sign, the illumination of the street is five times as great when the signs are in operation as it is when sole dependence is placed upon the street lighting system.¹²

Lighting of Public Buildings.—Libraries are probably of greater reference value in time of war than in time of peace. The lighting of libraries is notoriously inadequate, and ought to be increased as well as improved. University and college buildings may offer some opportunity for diminished illumination by reason of the decreased number of students occasioned by the war. Schools, like libraries, are generally inadequately lighted. Federal and municipal buildings require the usual amount of light, to the end that public work may not be impeded.

Industrial Lighting.—Progressive manufacturers have devoted a good deal of attention in recent years to lighting. Good factory management requires liberal lighting, and good lighting. While statistics are difficult to obtain, yet it is generally believed by those who have devoted attention to the subject, that production is increased, shrinkage reduced and accidents avoided through adequate lighting.

Recent tests made in a machine shop of one of the large Chicago concerns under the direction of the Lighting Committee of the Commonwealth Edison Company showed from 8 to 27 per cent. increase in production when the lighting intensity was increased from 4 to 12 foot-candles. These figures cover eight different operations which averaged a 15 per cent. increase. For each intensity a carefully designed system with deep bowl steel reflectors was used, and every precaution was taken to insure fair results.¹³

As increased light promotes production, so diminished light reduces production. If to save coal, production must be curtailed, it is an interesting question if it is more economical to reduce the lighting and effect a small coal saving, or to reduce the heating and effect a larger coal saving, or to close the plant for a short time and effect a still larger coal saving. Whatever the answer may be in a particular plant, it will be found that but small coal saving may be effected by curtailing the lighting as compared with that which can be effected by other means.

Real economy in such case dictates the use of slightly more coal, if the coal is available, and permits a curtailment of the lighting only if the coal shortage is such as to make it necessary to accept a serious falling off in production. Many of the older industrial plants and most of the small factories are not adequately lighted. In time of war and labor shortage, when the utmost production from each worker must be had, industrial lighting should be increased rather than decreased.

Residence Lighting.—In some rooms which are used for social or recreational purposes, more light is used in some cases than esthetic or other considerations dictate. The greater number of rooms are underlighted. Modern life extends the hours of visual activity far into the night, imposing demands upon our visual organs which our forefathers never encountered. This greater demand, in combination with inadequacy and misuse of light, is transforming us into a bespectacled race. The menace of poor home lighting is particularly serious in the case of children, whose eyes, ophthalmologists tell us, are more liable to permanent injury through strain involved in near vision work under conditions of poor illumination than are the eyes of adults. The conclusion must be that considerable saving in lighting may be effected in the homes by greater diligence in extinguishing lamps at times when they are not needed, and by reduction of light in rooms which are not devoted to visual activities. Aside from this, the need in home lighting is for the use of more rather than less light. Ample light makes possible the use of diffusing safeguards which with less light would be discarded.

Protective Lighting.—In time of war, especially in a country which, like ours, harbors so many enemy aliens, the guarding of property which is important to the prosecution of the war and

to the welfare of the people, is a necessity. The labor shortage makes it difficult to provide a sufficient number of guards for the purpose, and guard labor involves large expense. The effectiveness of a guard at night depends in large part upon his ability to see all parts of the area entrusted to his care. Artificial lighting is, therefore, a very important factor in the protection of property. It alone makes night guard duty effective. It makes effective guarding possible with fewer guards. It tends to deter from attempts at depredation as well as to make it possible for guards to discover any menace.

The numerous attempts at interference with our industries prior to recognition of a state of war by this country led to some increase in the extent of protective lighting. During the past few months the increase in protective lighting has been rapid. Notwithstanding this, many points of vital importance are either unprotected by artificial lighting or are insufficiently protected. An increase of a number of times in the amount of protective lighting is urgently needed.

Commercial Lighting.—Stores of the better class employ adequate illumination at night. In a few cases excessive illumination may be found. (Show windows are considered to be included under advertising lighting.) Offices are practically never overlighted, and upon the whole may be said to require for best work, and therefore for best economy, somewhat more light than is generally used.

Recreational Lighting.—The importance of recreation at all times is generally recognized. Several forms of recreation are considered to be practically indispensable. Nevertheless, in times of emergency, recreation certainly takes a place secondary to many other activities in which artificial light is employed. Theatres, churches, dance halls; etc., generally are not overlighted. (Signs of course are included under advertising lighting.) Saloons are said to employ more light than is needed.

Advertising Lighting.—Advertising is a necessary factor in commercial success. Among advertising methods the employment of artificial light holds an important place. There are perhaps fewer objections to the elimination or reduction of advertising lighting than there are to the elimination or reduction of

most other classes of lighting, but curtailment of advertising lighting works damage to the business of those who utilize this form of advertisement just as would the curtailment of any other form of advertising. There are various degrees of importance of advertising lighting. All the complicated questions of priority are involved. The only measure of desirable curtailment of artificial lighting is the emergency which occasions the curtailment.

ESTIMATE OF PRACTICABLE CURTAILMENT.

The author has prepared the following rough estimates of the manner in which artificial light is distributed among the several classes of service adopted as a classification for this purpose. There are no general statistics on this subject. Some fragmentary data and the opinions of several men engaged in the lighting business have been obtained. It is to be emphasized, however, that these figures should not be accepted as anything more than very roughly approximate.

Beside these figures showing approximate distribution of lighting among the several classes of service are figures representing the consensus of opinion of twenty qualified observers¹⁴ as to the extent to which lighting in each class of service ought to be curtailed or increased in the present emergency. The values are probably reasonably indicative of expert opinion on this subject at the present time.

ADJUSTMENT OF ILLUMINATION WHICH ACCORDING TO EXPERT OPINION OUGHT TO BE MADE FROM STANDARDS EXISTING BEFORE THE WAR IN VIEW OF THE WAR AND THE FUEL SHORTAGE.

Class of lighting service	Per cent. distribution	Desirable adjust- ments, per cent.
Street	14	— 5
Public building	3	— 10
Industrial	19	+ 50
Protective	1	+200
Commercial	22	— 10
Residence	24	— 20
Recreational	7	— 40
Advertising	4	— 75
Miscellaneous	6	— 10
	<hr/> 100	<hr/> Net — 3

In presenting an advance copy of this paper before the New

York and Philadelphia meetings, the author stated that the consensus presented at that time included all opinions which had been received up to the time of going to press, and that opinions received later tended to make the assignment of net curtailment smaller than that shown in the advance copy. The net curtailment shown in the preliminary assignment was 7 per cent.* The present assignment, netting 2.9 per cent., includes all opinions which the author has received in response to his questionnaire. The conclusions stated in the advance copy based upon the 7 per cent. assignment are even more valid when the assignment has been made 3 per cent.

The total reduction in lighting indicated by the assignment in the foregoing consensus is 14.4 per cent. It is almost counter-balanced by an increase in lighting called for in industrial and protective lighting aggregating 11.5 per cent. of the whole. This leaves a net curtailment of 2.9 per cent. or say 3 per cent. It would appear to be equally the duty of the members of this Society to seek to bring about reduction in lighting where it can be accomplished without undue disadvantage and to seek to bring about increase in lighting where advantages can be gained. It is difficult to say which is the more important. In any event, the 3 per cent. net saving is the figure which should enter into our calculations of practicable lighting curtailment.

It will be recognized that both the extent of lighting and the level of illumination intensity in each class of lighting are involved in this survey. In protective lighting, for example, it is a more extensive application rather than higher intensity which is required. In industrial lighting, on the other hand, higher intensities are deemed advisable.

Desirable readjustment of artificial lighting to meet war conditions and to assist in meeting the coal shortage consists, there-

* Assignment of opinions included in the advance copy of the paper was as follows:

Class of lighting service	Per cent. distribution	Desirable adjustments in intensity, per cent.
Street	15	— 5
Public building	3	— 10
Industrial	18	+ 50
Protective	1	+200
Commercial	20	— 20
Residence	26	— 20
Recreational	7	— 40
Advertising	5	— 80
Miscellaneous	5	— 10
	100	Net — 7

fore, in eliminating extravagant and unnecessary light, in eliminating the use of lighting for unnecessary periods, in reducing the intensity in a few places, in increasing the intensity in a few classes of lighting and in extending lighting in other classes of service.

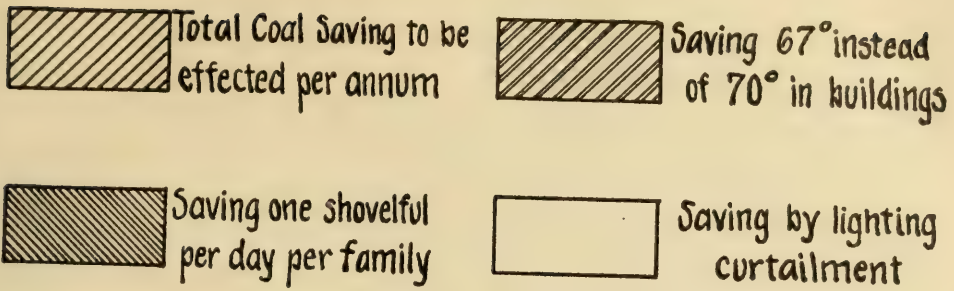
It is important to compare with the foregoing table that which appears on page 115. This comparison shows that in the opinion of lighting experts, electric lighting which to attain most desirable standards ought to have been increased by 72 per cent. before the war, ought now to be decreased by 3 per cent.

COAL SAVING THROUGH CURTAILMENT OF ELECTRIC LIGHTING.

It has been shown, page 126, that in the opinion of specialists lighting may be curtailed in certain classes of service to an aggregate of 14 per cent. of the total lighting; that in certain other classes of service lighting should be increased to an aggregate of 11 per cent.; and that there is therefore a net desirable curtailment of 3 per cent. which may be effected as an emergency measure in view of the war and the fuel shortage. If a proportional amount of coal saving be assumed, this would mean a reduction in coal consumption of 360,000 tons per annum.* This is the maximum extent to which it is believed that the best interests of the public require coal to be saved through electric lighting curtailment. Such a saving compares with other possible annual savings as follows:

Total annual saving which must be accomplished.....	50,000,000 tons ⁷
Savings within the control of the public—	
Net saving thought desirable through curtailment of electric lighting	360,000 tons ¹⁴
Saving if each family decreases by one shovelful its daily use of coal.....	15,000,000 tons ¹⁷
Saving by maintaining temperature of building interiors 3° lower, say 67° instead of 70° F.....	10,000,000 tons ⁹
Possible savings not within control of the general public—	
Saving by railroads through practicable light firing of locomotives	7,000,000 tons ¹⁹
Practicable savings requiring some time for consummation and not within the immediate control of the general public—	
By railroads through electrification.....	40,000,000 tons ²⁰
Accomplished by Chicago, Milwaukee & St. Paul Railway through electrification and utilization of water power on its Rocky Mountain Division...	500,000 tons ²¹
By substitution of central station power for private plants	13,000,000 tons ⁸

* Seven per cent. or 840,000 tons was estimated in the advance copy of this paper.



Total Coal—1917

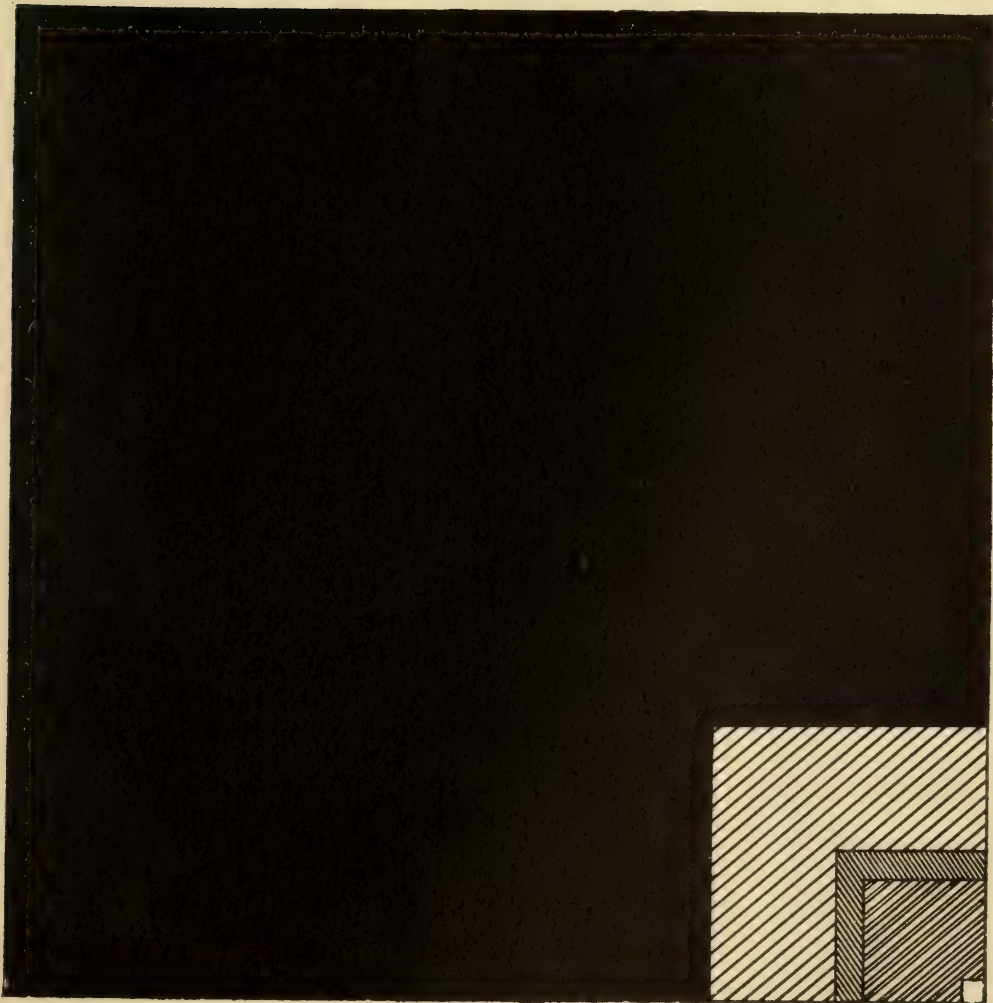


Fig. 2.—Savings in coal which it is practicable to effect through curtailment of lighting and by some other methods.

Coal saving through lighting curtailment can make only a small contribution to the total saving which must be effected. That small saving, however, should be made and to that end all means of reducing consumption for lighting which have been discussed favorably in this paper ought to be practiced. Yet with the utmost of patriotic action it is possible for those engaged in the lighting business and for the general public to accomplish only an insignificant part of the necessary saving through such means. It is therefore not with any desire to distract attention from the need for effecting saving through lighting curtailment, but rather in the hope of accomplishing greater savings otherwise that engineers must turn their own thoughts and the thoughts of the public toward other means of conserving coal. Among these, the possibilities through changing the practice of heating buildings are especially important.

AN ESSENTIAL DIFFERENCE BETWEEN COAL SAVING THROUGH LIGHTING CURTAILMENT AND CERTAIN OTHER COAL SAVING MEASURES.

A relatively small quantity of coal may be saved through curtailment of electric lighting. This is accomplished at the expense of a certain amount of damage to business. Most of it will fall on display and advertising lighting. As a consequence, the business of those who depend upon this form of advertising will suffer. The remainder of practicable lighting curtailment will fall in other classes of service where its principal effect may be annoyance and inconvenience. In both cases the revenues of lighting companies and of manufacturers of lighting appliances will be reduced. The only savings in artificial lighting which may be accomplished without disadvantage to business are those effected through the substitution of efficient for inefficient light sources, through the use of good and efficient lighting equipment and through good maintenance of lighting systems. There can be no question that these ought to be brought about, although they are not included in lighting curtailment.

Savings of coal through improved heating of buildings, through the maintenance of somewhat lower temperatures in buildings, through light firing of railway locomotives, through the substitution of central station for private plant power, through the elec-

trification of railways, etc., are savings through the elimination of waste and are comparable in this respect with savings in the lighting field which may be accomplished through the substitution of efficient for inefficient light sources. They are in a different class from savings of coal effected through lighting curtailment.

In view of this distinction and in view of the much greater coal savings which may be effected in other ways, it is to be hoped that the relative disadvantages of saving the very small amount of coal through lighting curtailment and through other means will be weighed most carefully.

CONCLUSIONS.

It would appear that members of the Illuminating Engineering Society have two duties to perform in the lighting field in the present emergency: (1) They should promote the elimination of waste in lighting; (2) they should promote the use of more light in the industries. Because but little coal can be saved in lighting, it would appear to be incumbent upon them to be even more diligent in the elimination of extravagance and waste in order to accomplish their part and to make possible the use of more light where it is needed for the purpose of promoting industry. At the same time it would appear that we have a duty to make known the facts in regard to lighting conditions and the relation of artificial lighting to coal consumption as well as to urge upon authorities and public alike, the importance of adjusting artificial lighting so as to promote the best interests of the country in the present contingency.

General curtailment of lighting would be a menace. For the last eleven years the Illuminating Engineering Society has devoted a large part of its effort to promoting good illumination. The research and investigation of its members on the effect of light upon the eye; the influence of its technical discussions upon design and installation of lighting appliances; its popular educational campaigns in the fundamentals of good lighting have resulted in improvement of lighting practice especially in the more recent installations. A small beginning has been made toward approximating daylight characteristics in artificial lighting. The important feature of daylight which we seek to emulate is diffu-

sion of light. Without this quality daylight intensity would be unbearable. In order that artificial light may be diffused an ample supply must be produced. If the quantity of light were reduced means for diffusing it would be discarded and it would be used in its raw or crude state. This would set back by ten years or so the development of the lighting art which has been in the interest of the public. It would do more, for in the interval much more brilliant light sources have been substituted for those of ten years ago. To remove light diffusing safeguards would leave these brilliant illuminants exposed.

In the author's judgment, general curtailment of lighting would result in damaging the eyesight and impairing the efficiency of our people. It would be wise only if the coal shortage should become so acute and distinct that the impairment to the human energy of the country would be preferable to the small amount of coal involved.

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2. Statistical Abstract, U. S. Dept. of Commerce, 1914.
3. Statistical Abstract, U. S. Dept. of Commerce, 1914.
4. Dr. Garfield before Senate Committee on Manufactures estimated January 1 to December 1, 1917, total coal output at about 575,000,000 tons. (*Coal Trade*, Jan. 2, 1918.)
5. Goodman and Jackson (*Proceedings A. I. E. E.*, Jan., 1918) estimate total consumption steam driven electric central stations for 1917 at 20,000,000 net tons. More recent estimates by T. C. Martin and W. C. Anderson of the N. E. L. A. point to a somewhat larger figure. Fifty per cent. output added for private plants.
6. Author estimates that one-third central station electric power goes into production of light. Somewhat smaller proportion for private plants.
7. Bulletin V, Jan. 4, 1918, Committee on Coal Conservation, Chamber of Commerce of the U. S.
8. Goodman and Jackson (*Proceedings A. I. E. E.*, Jan., 1918).
9. Computed for the author independently by E. F. Tweedy and E. D. Doyle that reduction from 70° to 67° will save about 10 per cent. of coal. Coal used for heating 110,000,000 tons—U. S. Geological Survey, 1915.

10. Assigned from estimates submitted by Messrs. F. C. Caldwell, J. R. Cravath, W. A. Durgin, C. L. Law, W. F. Little, M. Luckiesh, N. D. Macdonald, L. B. Marks, P. S. Millar, E. B. Rosa, C. H. Sharp, G. H. Stickney, F. A. Vaughn.
11. *Electrician*, March 2, 1917, p. 652.
12. Data by W. F. Little.
13. Investigation conducted by engineers of the Commonwealth Edison Company of Chicago in conjunction with proprietor of shop.
14. Distribution assigned from estimates by Messrs. J. R. Cravath, W. P. Hurley, W. F. Little, N. D. Macdonald, P. S. Millar, A. L. Powell, W. H. Rolinson, W. J. Serrill, C. H. Sharp, G. H. Stickney. Adjustment which ought to be made in view of the war and the fuel shortage assigned from opinions by these gentlemen and Messrs. W. C. Anderson, Louis Bell, W. A. Durgin, F. C. Caldwell, R. S. Hale, D. C. Jackson, C. L. Law, M. Luckiesh, L. B. Marks, T. C. Martin, R. F. Pierce, E. B. Rosa, A. J. Sweet, F. A. Vaughn.
15. Samuel Insull, *Electrical Review*, Jan., 1918.
16. Leon Gaster, *Electrician*, Dec. 22, 1916, p. 393.
17. Statement of Fuel Administration published in lay press.
18. *Electrician*, Dec. 28, 1917, p. 504.
19. M. A. Daly, Fuel Supervisor Northern Pacific Railway, reported in lay press.
20. E. W. Rice, Lynn Section A. I. E. E., Feb. 2, 1918.
21. *Electrical World*, Jan. 5, 1918, p. 59.

APPENDIX.

CONSERVATION IN USE OF COAL.

COMMITTEE ON COAL CONSERVATION.

Chamber of Commerce of the United States
Riggs Building, Washington, D. C.

Bulletin V.

SMALL SAVINGS THAT COUNT.

*To the Members of the Chamber of Commerce
of the United States:*

The shortage of coal for every day of the ensuing year amounts to about 40 ounces or 2½ pounds for every man, woman and child in the United States. Great economies in the use of coal will be effected by the factories, the central heating, lighting and power plants and the railroads. But small savings must not be neglected. Some opportunity is presented

to every person every day to save coal by reducing the consumption of heat, light or power. The responsibility for making these savings is widely diffused among millions of people. The aggregate importance of them is correspondingly great.

Every ounce of coal saved is an outright contribution to the nation's war-time need for fuel. Some persons may easily save their entire quota of 40 ounces each day. The following schedule suggests some of the means for saving small quantities of coal. These savings, in the aggregate, will set free thousands of tons of coal for the industries of the country, for the railroads, for the navy, and for the ships that carry our men and supplies to France.

Conserve Electric Light; electric current usually comes from coal.

Consult your dealer as to the most economical types of lamps suitable to your conditions and fixtures. A 25-watt lamp used instead of a 40-watt lamp saves at least an ounce of coal every two hours.

Turn Lights Off When Not Needed; if a 25-watt lamp or an ordinary gas light is turned off, even for short intervals, the aggregate saving may easily be an ounce of coal a day for each lamp.

Discard Carbon Filament Lamps; substituting a 25-watt tungsten lamp for a 16-candlepower carbon filament lamp provides a better light and saves 2 or 3 ounces of coal every day.

Burn Gas in Mantles, Not in Flat-Flame Burners; the old fashioned flat-flame gas light burner uses more than twice as much gas as a mantle burner giving more light. Each mantle burner substituted for a flat-flame burner will save probably not less than an ounce of coal a day.

Use Substitute Fuels; many kinds of fuel are available to supplement the coal supply. The waste material, such as "hog chips" of lumber mills, as well as brush wood, broken boxes, corn cobs, etc., may be pressed into service.

Attend to the Lubrication of Machinery; a drop of oil will often save an ounce of coal. Careful attention to the lubrication of all working parts of machinery will save many pounds of coal in the day.

Do not Super-Heat Rooms; observing the thermometer and turning off radiators to hold the temperature below 70° reduces the load on the heating plant.

Conserve All Heat and Power; keep in mind that every loss of heat or power is a loss of coal. A leak in a steam connection and a super-heated office room are alike the cause of wasted coal. Keeping a heavy power unit in operation when a lighter one would carry the load wastes coal, and so does all unnecessary use of electric elevators in office buildings.

Use Weather Stripping and Storm Windows; a bit of weather stripping about the door and the use of storm windows in offices, schools and all buildings that are heated, will reduce the burden on the heating plant and make effective a daily saving of coal.

Discourage Electric Display Illumination; this use of coal is not absolutely necessary. The genius for advertising which originated this excellent method of display should find temporarily other means of expression. Eliminating or foregoing an electric sign may save tons of coal a year.

These methods of saving heat, light and power are not unfamiliar. Everyone, perhaps, will think of some effective means of saving which is not included in this list. The important idea to be impressed on every person is that a great need exists for saving coal and that even small savings must not be overlooked.

Saving coal is not always identical with economy to the person effecting the saving. It may be someone's else coal that is saved; or the time and expense required to effect the saving may offset the money advantage. Nevertheless, it is a patriotic duty now to save coal at any reasonable expenditure of time and material. And in the majority of cases, there will be a direct or indirect advantage to the person entitled to the credit for the saving.

A voluntary, universal response to the call for saving coal in the many small ways that present themselves every day, will insure the success of the great efforts at fuel retrenchment which are now being made in the industries and by central plants.

COMMITTEE ON COAL CONSERVATION OF THE
CHAMBER OF COMMERCE OF THE UNITED STATES,
By ERNEST T. TRIGG, *Chairman*.

January 4, 1918.

Any member of the National Chamber that wishes to distribute copies of this bulletin can obtain them by addressing the General Secretary, Riggs Building, Washington, D. C. Coal dealers who supply small plants should be in a very advantageous position to distribute copies to their customers.

DISCUSSION.

PRESIDENT G. H. STICKNEY: When the United States undertook the serious business of war, a new condition obtained whereupon war became the dominating effort of the nation, before which all other affairs must yield more or less.

Many activities in the pursuit of happiness which were commendable a year ago must now be discontinued or restricted, lest they interfere with our struggle for victory. Art may have to descend from its pedestal and many luxuries be dispensed with until the "monster" is conquered.

In this, lighting is no exception. On the other hand, it must be recognized that all lighting is not on a par. There are many applications in which the country's interest will permit of no curtailment, but may actually demand extension.

Light is an important factor in warfare as well as in manufacture, transportation and other activities in support of the war.

While the Illuminating Engineering Society is interested in developing the lighting art, it has recognized that this aim must be subordinated to the one essential of winning the war.

The Society has been particularly fortunate in finding opportunities of serving the Government efficiently, and in this connection is indebted to the National Committee on Gas and Electric Service.

Mr. Millar, as Chairman of the War Service Committee, has organized and directed some of the most important service which we have rendered. In fact, this meeting was arranged for the purpose of contributing to that service by patriotically bringing out valuable facts and opinions regarding the relation of lighting to the war problem of fuel conservation.

JOHN W. LIEB: The committee which I have the honor to represent, the National Committee on Gas and Electric Service, is fortunate in having among the various national societies co-operating with it, the Illuminating Engineering Society, and I wish at this time to take the opportunity of expressing the appreciation of our Committee for the effective co-operation rendered by the Illuminating Engineering Society, and the readiness and enthusiasm with which the members of your Committee on War Service responded to the repeated calls which were made by various departments of the United States Government through our National Committee, and which were passed on to this Society.

The subject which has been presented in Mr. Millar's paper was one which was brought to the attention of the National Committee on Gas and Electric Service at a very early stage of its work. Soon after the organization of the Committee on Coal Production of the Council of National Defense, a number of communications were sent to that committee, calling attention to various phases of fuel conservation, and various ways in which waste could be eliminated, and economies in the use of coal

undertaken. I wish to present one or two letters in that connection, and I do so for the purpose of showing the attitude which the public utility companies—the electric lighting companies—took on this general question, and more especially on the question of sign lighting, which was the phase of fuel conservation first brought forward.

The first reference appears in a letter which the National Committee directed to an inquirer who sent a communication to Washington. This letter bears the date of July 24, 1917. After the introduction, these statements appear:

"This subject—(referring to the large amount of coal that was said to be wasted in electric signs)—has been discussed to some extent in the public press, and being a subject that makes visual appeal to a large number of people, it should be given very careful consideration. The prevalent public opinion, that these display signs of various kinds represent, through the energy they consume, a very large amount of coal, is quite without foundation. Statistics obtained from a number of our large cities indicate that electric signs and special white-way lighting of all kinds represent combined a consumption of electric currents, amounting in various cities, to from 0.3 per cent. to a maximum of 1 per cent. of the total output of the power houses, a fair average being probably 0.6 per cent.

"To eliminate the use of this display lighting would, however, result in a saving of coal in a lesser proportion, and the actual saving would probably be less than one-half of 1 per cent. The reason of this relatively small energy consumption and consequent saving is due to the fact that the lamps used are tungsten lamps of the very smallest sizes, consuming only $7\frac{1}{2}$ to 10 watts each, or approximately 100 to 130 lamps to the kilowatt. It appears to the public, therefore, that coal is being consumed wastefully and money expended unnecessarily to a far greater extent than is actually the case.

"It is true, however, that the uninformed public, observing this resplendent display, may consider that it is inconsistent for the public authorities to urge economy and conservation of our resources while the attention of the people is nightly riveted to what appears to them to be a display of extravagance and waste.

"There are, however, other points of view which should be taken into consideration. The smaller electric sign in front of the individual store is an appealing form of advertising attraction to the small merchant, who finds it impracticable to make use of the columns of the daily press. Shutting off of display lighting would be a serious disadvantage to the small merchant.

"Again, in our large cities this 'white way' lighting of various kinds form one of the attractions of our great centers of population, brings

strangers and visitors to them, and constitutes a welcome diversion to the volunteer or recruit who may be awaiting his call for military service.

"It has been the experience abroad that cheerful surroundings and a certain amount of gayety have a very favorable effect on the convalescence of the wounded soldiers, while gloomy surroundings have a depressing and unfavorable effect. It is for this reason that our Allies have found it necessary, while prohibiting street illuminations and displays in order not to attract hostile air craft, to maintain theatres, moving picture shows and other forms of entertainment to help cheer up the soldier on leave of absence and make enjoyable his short stay in 'blighty.' It would appear, therefore, that the situation is one of psychology rather than of economy, one of impression than of notable waste.

"In making a decision, therefore, as to the wisdom or desirability of eliminating this 'white way' lighting, all of these points of view must be taken into account.

"If it should appear important to the national or municipal authorities in the public interest to eliminate this display lighting, I feel very sure that the lighting and power companies would co-operate in every practicable way toward this end. They would not allow the effect on the revenue that would result from cutting off this consumption to stand in the way of accomplishing an important public purpose if it should appear that, taking everything into consideration, it was important in the public interest to eliminate even the appearance of waste or extravagance."

I wish also to read resolutions, which were adopted by the National Committee on Gas and Electric Service, and filed with the Fuel Administrator, Dr. Garfield, under date of November 1, 1917, which I think clearly set forth the attitude of the central stations of the country toward this subject.

WHEREAS, Under the extraordinary conditions arising out of the state of war, the public is visually impressed by the apparent waste of fuel which it believes to be involved in the lighting of the electric display signs, so conspicuous a feature of the life of our larger cities, notwithstanding the fact that, even in the aggregate throughout the country, this service requires the consumption of an inconsiderable percentage of the total coal required for the operation of electric power plants generating electrical energy; and

WHEREAS, The continued use of such electric signs apparently renders more difficult of consummation the efforts being made by the national authorities to urge the public to conserve and economize in the consumption of all the necessities of life and the elimination of all waste and extravagance, real and apparent, in the use of the commodities essential to our nation and its allies in the successful prosecution of the war; and

WHEREAS, Exterior display lighting of the different kinds is of varying degrees of necessity and importance to the general public and to the business communities in which it is operated, depending upon the immediate purpose which it serves; and

WHEREAS, If and when the national authorities decide that the time has arrived when it shall appear to them to be necessary in the national interest and for the purpose of impressing on the people the importance of avoiding all waste and extravagance, to call public attention to the necessity of practicing economy in the use of fuel in industries, in the factory and in the homes of the people, they should then issue a pronouncement to the people of the United States requesting them, under the supervision and direction of the proper State and municipal authorities, to limit the use and operation of advertising, billboard and display signs, exterior publicity lighting and special ornamental street lighting of every kind, to that which is important and necessary for the convenience and safety of the public and for the proper conduct of the various business and commercial enterprises in the respective communities, and to render effective their co-operation in this work, be it therefore,

Resolved, That the public utility companies throughout the United States through their organizations, the National Committee on Gas and Electric Service, of the Council of National Defense, representing the gas companies—manufactured and natural gas—the electric light and power companies, the water works companies and the central steam heating companies throughout the country, pledge their hearty support and co-operation to the national authorities in carrying out any plan or regulation for the saving of fuel, gas, oil, or electricity which the national authorities in the public interest may consider it necessary to adopt, as a war measure.

In this question of the suppression or limitation of the use of electric signs, the public utility companies have been placed in a somewhat difficult position. On the one hand, it is undeniable that the central station companies had for years past made every effort to stimulate that appealing form of advertising—a form which was at the same time an advertisement for the customers, an advertisement for the central station company, and an advertisement for the general public. For the lighting companies to have indicated an attitude of indifference to the welfare of this class of business, which it had done so much to stimulate, would have been, from the standpoint of the sign customer and the sign manufacturer, an unfair and an unwarranted attitude. On the other hand, a disregard of the appeal that it was an obvious thing to do to place electric signs under limitation, would have placed the central station companies in the unpatriotic attitude of having a greater regard for the maintenance of revenues than for the national welfare. This difficult phase of the situation made it necessary, and I may say, desirable, for the central station companies to come out with such a pronouncement as has

been read to you this evening, in order to go on record, that their purposes in this matter were entirely patriotic—that it was a national question for the national government to handle, and that the attitude of the companies was in no wise one of selfish interest, but was the broad one of a national purpose, which they were most anxious to serve.

Many times the question has been asked: "What actual coal saving has resulted from the 'lightless' nights?" In the communication which I read a moment ago the anticipated saving was stated on the assumption that all exterior illumination would be dispensed with. The actual saving which has been accomplished is very difficult of determination. In these times central stations must use coal of poor quality, resulting in variations in consumption from day to day ranging up to 10 and 15 per cent. Under these conditions the difficulty will be evident of locating a saving of say $\frac{1}{2}$ per cent. due to elimination of sign lighting.

Referring to the recent five days of curtailed industry, it may be said that in general the reduction in coal consumption through the lesser use of light and power was of the order of 25 per cent. The reduction on Monday under the regulations of the Fuel Administration has approximated 35 per cent.

I wish to say, in closing, that the Illuminating Engineering Society, as well as every other phase of technical and professional engineering activity, has an important work to do, and I feel very sure that the Illuminating Engineering Society will continue, as it has in the past, to respond with enthusiasm to the call which is being constantly made to an increasing extent, by the national government for aid and assistance in solving some of these momentous problems which are now pressing upon it.

C. W. CUTLER: I have heard Mr. Millar's paper with much interest and can only add my approval to the main thesis, that artificial illumination has become indispensable for the increasing complexity of the night work, and granting that the ever growing complexity of life is inevitable, more light rather than less is needed in factories, printing offices and other places where fine work must be done under difficulties.

With regard to the streets, one would not wish to go back to the days I remember in New England, where the street lamps

were lighted when the almanac declared that there was no moon, but I would take exception to the statement that street signs are an essential part of street lighting. Let me quote from a recent article on sign lighting:

"The big value of illuminated signs to any community lies in their wonderful brightening, boosting, and cheering influence. Compare any two towns with and without these signs. The one is alive, while the other is dead."

This is quite true and any protest must seem reactionary, but let us substitute "asleep" or "resting" for "dead" and the conservative has at least a fair ground to stand on. One might as well raise one's voice against the profusion of the daily press, an equal embarrassment of riches, which grows by the needs it creates; yet there are some who feel that true philosophy and enjoyment of life are not furthered in these ways.

In general terms these may be taken as the feelings of a silent, perhaps a sleeping fraction of the community, though not a dead one, based on two main points:

1. That exaggerations of all kinds are stimulations which lead to reactions of various kinds, chiefly nervous, which are apt to become abnormal, and

2. That the lure of the streets and public places is putting an end to what was once an asset of our country, the home life, the contentment with simpler pleasures.

These excesses, if they really are evils and not phases of social evolution, are inseparable from all material prosperity and must be accepted, but it does rest with you gentlemen to so lead and moderate the public demand that the esthetic and the hygienic ideals shall not be forgotten.

A great deal more might be said regarding the effects of light, perfect though it may be and simulating to the closest degree possible, in distribution and quantity, the daylight, under which the eye has evolved; but the eye has not been adapted to use during eighteen hours a day under the stimulation of working conditions, and although it may stand the strain, our nervous resistance seems less, and the first sign of fatigue is excessive irritability and what may seem to be increased efficiency, but which is in reality the beginning of exhaustion or at least of diminished resistance.

We are living, not only at this moment, but in this age, under a stress for which we have not yet become adapted, and much of the hysteria and well recognized nervous reactions called neuroses and psychoses are simply our reactions to our environment and the effect of the stimuli with which we are surrounded. Competition, which has made the night work necessary, accompanied by the sensory stimuli to the eye and ear, as well as to the palate, is blinding us to a true comprehension of our relations to our environment, and shortening our perspective dangerously.

I feel that this statement may be considered quite out of place in a discussion of an economic question, and I offer my apologies for taking your time, but even though the saving of light is not of great importance, as Mr. Millar has stated, as a matter of economy of resources, it may be of value as a means of saving energy and as the beginnings of the return to a simpler mode of life in which mankind will not be less happy.

The changes to which the present generation has had to adjust itself are marvelous and it is those who experience the transition who pay the price. Most that the increased flood of light has given us is in the highest degree beneficial, but it has quickened the pace and the pulse of life and there are some who will not keep up. I speak as a physician.

I have watched with much interest the careful way in which your Committee on Lighting Legislation has dealt with the difficult problems of *factory* and *school lighting*, and it is reassuring to know that these important questions are in such hands. It is the children and the working classes whose conditions have been most unfavorable in the past and it is good to think that the boon of light, under the efficient control of this Society, is making their difficult growth and work easier and safer, and it is self-evident that curtailment along these lines would be little short of criminal.

M. G. LLOYD: With thousands of people suffering from the cold and with the manufacture of munitions of war interrupted as they have been in recent weeks, I feel that any consideration of interference of business in connection with this matter must not be regarded as important. As a prominent representative

of the central station industry has said to-night, that industry would probably not lay great stress upon this phase of the question.

In trying to save fuel, however, the human eye ought not to be sacrificed. Suffering from cold is usually temporary and soon forgotten, but if the eye meets with a deformity it will probably never become normal again, and we know that the eyes, especially those of children, are likely to become deformed through the strain brought about by insufficient illumination.

When we consider the use of electric light in advertising, however, the question of impairment of vision is not usually involved. Most of us will agree that it is justifiable to temporarily discontinue this use of electric current in the interest of saving fuel. It does seem, however, like saving at the spigot while wasting at the bunghole. Wherever I go I am impressed with the waste of fuel for heating purposes. When riding in railroad trains the cars are frequently overheated. In visiting the apartments of my friends I find them overheated. We are meeting in an overheated room to-night. The thermometer on the wall indicates 74° which we can probably all agree is too high for either health or comfort. Not only are residences and other buildings overheated, but coal is used very inefficiently in them. Much coal passes through the furnaces without being consumed and the heat actually developed is used inefficiently.

In industrial plants we have a condition which is probably not quite so bad, but which is in dire need of improvement. Every mechanical engineer who has looked into the proposition knows that the average power plant is not operated efficiently and does not operate with the economy of fuel which engineers know how to obtain. An exception to this statement should probably be made in the case of the power plants of the big utility companies and a few power plants of industrial concerns. Many private power plants, however, are open to severe indictment on this score, as brought out by Mr. Myers in his recent article.* He and other engineers who have specialized on this subject do not hesitate to make the statement that a quarter, or perhaps a third, of the fuel used in the average power plant to-day could be saved if it were operated to the best advantage and as our best engi-

* D. M. Myers, *Journal of the A. S. M. E.*, Vol. 39, p. 901 (Nov., 1917), "Preventable Waste of Coal in U. S."

neers know how to operate it. He mentioned one big steel plant where by suitable management 40,000 tons of coal could be saved annually. When we consider the total consumption of coal in the industrial power plants of the country, if the same ratio would obtain it means that we could save more than enough coal to make up the estimated shortage. To put it in other words, coal representing the capacity of 1,500,000 coal cars could be saved annually if the fuel were used with an efficiency which we know how to obtain.

It seems very evident that while saving at the spigot we should also save at the bung-hole. I should like to see the Fuel Administration conduct a campaign along the same lines as that of the Food Administration, and bring home to every power-plant operator and to every citizen who operates a furnace on his premises the necessity of making the best use of the fuel which he consumes. There have been recommendations for use of weather stripping, storm-windows, etc., and we have probably all heard the suggestion with respect to saving a shovelful of coal per day, but such suggestions have not been driven home to the people as have been the admonitions of the Food Administration. If they were I think they might be much more effective. What we need, however, is not merely an admonition to save a shovelful of coal, but people must be told how to save that shovelful, and then we might expect them to get some results.

In the paper by Goodman and Jackson which the author has referred to, the statement was made that the coal being received by the power plants for consumption is not of as good quality as that received previous to the war. From my own observation I should say that the same is true of the coal now being used for other purposes. Residents in my own neighborhood have had coal delivered to them of such a quality that it was impossible to burn it in an ordinary furnace. In some cases it was nothing but dust or slack. In other cases there was a large proportion of slate or other foreign matter in it. The coal operators have frequently been reported to have said, and I have seen the statement made by the Secretary of the Coal Operators' Association, that the difficulty in this winter's situation has not been at the coal mines. The miners have been able to produce enough coal, but the coal could not be transported to the consumer. Lack of

transportation facilities has been the principal difficulty and the source of the break-down.

If this is true there is no excuse for shipping such poor grades of coal around the country and congesting the railroad facilities which ought to be better employed than by sending material to the consumer that cannot be burned. If some control were exercised by the Fuel Administration or by some other authority over the grade of coal that was shipped, undoubtedly a good part of the actual shortage could be eliminated. There might be an excuse for poor quality in coal if poor quality were essential to getting sufficient coal out of the mine, but with the mines able to produce more coal than can be transported I cannot see that there is any excuse for shipping the lowest grades of coal. It looks like a case of pure profiteering.

Goodman and Jackson estimated that the increased consumption due to poor quality was 10 per cent. Let us suppose that this applies to the entire coal output of the country. Using the figures given in the paper, this gives an additional consumption of 64,000,000 tons, which is more than the estimated shortage. Here then seems to be another point where a decided improvement could be made. If this vast waste on a large scale could be eliminated, the little saving that is accomplished by cutting down the amount of electric light would be entirely unnecessary.

FRANK W. SMITH: I hope it will be possible, through the medium of this Society and other proper channels, to give this presentation wide publicity. I was interested in Mr. Lieb's statement as to the New York Fuel Administrator's activities in the matter of coal conservation. The local gas and electric lighting companies were early called into conference with the State Fuel Administrator, and the co-operation of the companies was asked in the matter of suggested methods for the saving of fuel. Suggestions were made by the sub-committee appointed from the representatives of the local companies, that included a number of the suggestions set forth in Mr. Millar's paper.

The "lightless nights" together with the restrictions on window lighting, etc., were decided upon by the Fuel Administrator largely, I think, from the psychological point of view. At the request of the local administrator, the gas and electric lighting

companies sent to their consumers, 1,700,000 in number, a communication pointing out the necessity of economy in the use of light, and attracting attention to other methods of saving, several of which are mentioned in Mr. Millar's paper. This card was printed and circulated by the companies at their own expense. The suggestions included the following: burn fewer lights—turn lights off when not needed—burn gas in mantles, not in flat-flame burners—maintain a temperature not exceeding 68°, etc.

There is an important item of which brief mention is made in the paper, that is, the question of the use of inefficient incandescent lamps. It is important to point out that of the 145,000,000 lamps sold in the United States, during 1916, more than 16 per cent. were of the carbon and Gem type. A very material saving in fuel would result from the substitution of more efficient lamps. Some central station companies, although but few, are still using the carbon type of lamp. The Lamp Committee of the National Electric Light Association has addressed itself to this subject during the past year and has in preparation further publicity on the subject.

LOUIS BELL: We must approach this question with the realization that we are facing a great national crisis—by far the greatest in our history. We are in the war of the ages—to stay in it until it is won—and we have got to make every move, to make every sacrifice, without whimpering, until that end is attained. Now, in this matter of the saving of light, I am sure every man in this room, engineer or representative of a central station, will do all he can to see that the use of light is economized, first, last, and always, so far as it is important for the saving of fuel, and so far as that saving does not interfere with his country's efficiency. Mr. Millar has shown us, with admirable clearness, how petty and small and silly some of the attempts at curtailment look. They are not the real thing. They are only camouflage of the most foolish kind. A little can be saved here, a few tons here, a few tons there, but nothing important as yet. The time may come when we shall have to save light for the sake of giving power for making munitions. When that time comes, we will give up the light, and turn the power into motors, and do

it thankfully. The main thing is efficiency, right now, here and always.

What our Fuel Administration should do is to drive hard at the things that have been mentioned here—at the unnecessary wastes—at the wastes which are unnecessary in each individual home, and at the wastes, which are unnecessary and inexcusable, in the keeping up of business which has nothing whatever to do with driving forward to our great end. An eminent friend of mine, a chemical engineer, made a careful study a few years ago, as to the amount of fuel which is absolutely wasted by inefficient and useless combustion—wasted in the stove or the furnace; and from a very thorough and exhaustive sampling of contents of ash-cans, he made out that the waste of fuel, through absolutely ineffective combustion, through foolish extravagance, in inefficient heating apparatus, amounted to more than 20 per cent. That is more than all the saving we have got to make, and that waste occurs every day in ranges and furnaces all over the country. Now if you stop to think what the average range and furnace takes in the matter of fuel, you will very easily reckon that the saving which could be made simply by decent and economic use of the fuel, which we now throw away, would be more than enough to light every house that has to be lighted in this country. The waste in the actual average household per day is enough if burnt under the boilers of a central station to take care of the lighting of that house, and probably another besides. And so, what we wish our Fuel Administration would do, before it turns to the central stations, to ask them to curtail the output, or simultaneously with that demand—for we are willing to take our medicine with the rest—is that it should get after the evident and clear waste.

The central stations of the country, which are willing to bear their burdens manfully, are all regulated industries. Their prices and their manners and morals are strictly under governmental control, and I think that they have, therefore, a right to ask that the government should take other things under its control before it puts the screws on those who are willing to stand by it. That is the only complaint, I think, that the central station industry has to make. These are times when the utmost efforts of the government should be spent in suppressing those who are

wastefully and wilfully throwing away the resources of the country and striving to make personal profit out of the necessities of a national crisis.

It was the head of a large corporation doing government work, who only yesterday responded to a Senator of the United States, when he was faced with the \$6,000,000 profit that he expected to make, "Oh well, one can't run a corporation on patriotism." Well what I want to impress here, and I believe every man in this room will agree with me, is that if the time comes for us to make answer, it will be, "*In time of need, we will!*"

WM. A. DURGIN: Isn't this entire question of curtailing the use of light simply one more case of the obvious expedient? Of the three necessities, heat, power and light, rooted directly in our lamentably diminished coal pile, but one, *light*, is visible. To the legislator or administrator caught unprepared in a crisis and under the American compulsion to do something quickly, restriction of the visible consumer no doubt appears the obvious first step.

Two per cent. of the fuel consumed is utilized largely in the most efficient heat transforming devices our engineers have been able to develop and under the direct supervision of fuel consumption experts. The 30 per cent. consumed principally in the haphazard heating contraptions designed by foundrymen, and under the cursory attention of irritated householders, irresponsible janitors, or itinerant servants. Competent men believe that a full one-third of that 30 per cent., 10 per cent. of our entire coal consumption, can be saved by lower temperature levels, more intelligent firing, and better efficiency of heating plants. Cutting the enthusiast's estimate in half, taking 5 per cent. as an attainable saving, isn't that worthy the concentration of all our best effort, the application of all our fuel commission's abilities?

At present with every desire to serve in this crisis, where can we get intelligent direction? How many of you householders know where to obtain reliable advice on simple changes in your heating plants which will enable you to save one-sixth of your consumption? I am not speaking of complex changes such as grates, ash-pits, and other ideal arrangements, but rather of the small points; the best cement for leaks in casings, the most easily

applied lagging for pipes, or data from trials of various schemes of damper manipulation in houses like your own. Where can we buy cheap humidifying apparatus which shall make 62° or 63° as comfortable as 72° or 73° was? Presentation of points like these over and over again in every possible form of publicity will effect conservation out of all proportion to that resulting from substitution of 25- for 40-watt lamps.

In our ship yards, in our munitions plants, in the manufacture of necessities, the urge is for greater and still greater output. Higher intensities of lighting have been shown dispassionately and without prejudice to give a notable increase at a negligible cost with the same men and the same machines. And yet our attention is directed to the fact that the substitution of a 25- for a 40-watt lamp will save half an ounce of coal in one hour—that amounts to nearly a ton in a hundred years! Let us lighting men offer our services to our Government then, not for curtailing a non-existent luxury, but rather for applying better light and more light to winning this war—for utilizing light as a real weapon for victory.

W. D'A. RYAN: We are urged to economize in the use of light mainly for two reasons: to save coal and for psychological effects, while the actual coal saving made possible by the extinction of electric signs is small in comparison with practical savings in other directions; nevertheless it is our duty to economize wherever possible in order to assist in the successful prosecution of the war.

I am particularly interested in the statement that the average estimate of thirteen engineers engaged in lighting work indicates that the present standard of illumination should be raised approximately 73 per cent. in order to conform to their ideas as to desirable intensities. This is certainly very conservative. It is my personal opinion that both industrial and street lighting intensities could readily be increased from 100 to 200 per cent. with marked advantages to all concerned.

At the present time, manufacturers and industrial workers are being educated, under forced draft, so to speak, in the use of more and better light and as a result I believe we will find that say five years after the close of the war industrial lighting in

this country will be at least 150 per cent. higher intensity than at the beginning of the war.

I recently had occasion to compare some of the modern lighting installations with lighting recommendations which we made in the years 1901, 1902, 1903 and 1904. These included machine shops, textile mills and manufacturing plants in general, lighted mainly with arc lamps, concentric diffusers and concentrating mirror reflectors in high bays, which anticipated the present semi-indirect and direct lighting systems. It was interesting to note that $\frac{3}{4}$ watt per square foot was the average energy recommended for advanced lighting in the period mentioned. This figure has remained constant, but the foot-candle illumination to-day will run three or four times as high, showing that the increase in efficiency of lighting units and improved reflectoring has been fully utilized without compromising on the power consumed. A general increase to $1\frac{1}{4}$ or even to $1\frac{1}{2}$ watts per square foot with present unit efficiencies is absolutely justified and should not be regarded as reaching a point of extravagance.

As Mr. Millar points out—street lighting generally is inadequate and only an insignificant proportion of the streets are lighted to such an extent as to make it advisable to curtail lighting even in the times of fuel shortage. It is just as important to keep our principal streets well illuminated for police protection and the minimizing of accidents as it is to employ protective flood lighting for industrial plants. An eastern city recently reduced its so-called white way street illumination in addition to cutting off the signs, for three nights, and crime and nuisance had increased so much that it was necessary to restore the regular street lighting service. I feel that it would be unfortunate if it becomes necessary to make further curtailment of street lighting, especially in the case of water power operated plants where there is sufficient energy available to take care of increased manufacturing demands.

W. H. ROBINSON: I am heartily in sympathy with all of the statements made by the author of the paper. I believe the paper should have publicity. There are a good many among us who can give this paper national publicity and I think it would be

well if they would consider seriously the propriety of making such distribution.

W. J. HAMMER: Dr. Lloyd brought up a point which struck me very forcibly and that was the necessity of stimulating the saving of coal in our homes as is done in the methods of food conservation employed by the Food Administration.

The facts should be strongly brought home to the masses, that they should use their fires more intelligently and efficiently, shut off or bank their fires when not needed, prevent escape of heat and keep down the temperature of their overheated rooms; they should also turn off unnecessary lights and where practicable using smaller units of light, they would thus enormously assist in that conservation of coal which is of such paramount importance at the present time.

NORMAN MACBETH: I feel as Dr. Lloyd stated that the effectiveness of these conservation bulletins depends upon the extent to which they reach and are given attention by the individual. From the standpoint of the individual householder certainly very much greater coal savings can be effected along the line of conservation of heat with weather stripping, storm windows, elimination of excess radiation, and the maintenance of lower temperatures generally, rather than through savings of light, even to the extent of the hardship of going without light altogether.

The coal that would be saved in my home through reduction or elimination of lighting service is certainly not the kind of coal that could be used in a house-heating boiler. If a saving of one shovelful of coal per day per household will result in a total annual saving of 15,000,000 tons, and the saving which must be accomplished is 50,000,000 tons, I estimate my saving on the basis of 150,000,000 tons. This saving was effected generally in three ways. The steam mains in the basement were bare and painted black; on the advice of the consulting heating engineer that by properly heating the basement you could more easily warm the rest of the house. I reduced the radiation from this piping with sectional asbestos covering which I put on at a slight expense and which has resulted in the reduction of coal consumption of at least 25 per cent. Then, in one room which was not

used and in two bedrooms, the radiators were turned off. Closer attention was also given to damper regulations and the maintenance of a temperature not exceeding 68° in those rooms where the radiators were in use. By the use of heavier underwear we can easily get along with very much lower temperatures than are used in most homes. It seems to me unfortunate that the Chamber of Commerce bulletins gave so little attention to these important means of coal conservation in comparison to the importance attributed to saving by a reduction in the use of light.

A great deal of attention has also been given to curtailment of display lighting, a large part of which, if not all, is a form of advertising. There can be no question raised at this date that advertising electrically justifies its cost. If the stand is taken, however, that any form of advertising which results in an expenditure of fuel should be curtailed, then I believe that attention should also be given to the display advertising in magazines and newspapers, a comparatively few pages of which are exclusively editorial. A single saving of 15 to 30 minutes in the running of a large newspaper or magazine press once a month would save sufficient fuel to light the average house for an entire month. The curtailing of large display advertising in the newspapers and magazines would more than offset the energy required for the electric signs of small merchants who cannot afford to advertise in the newspapers.

Mr. Millar had an exceedingly difficult subject to handle that it might not appear that his paper was merely a protest against interference of the business of the central station. The point should not be overlooked, however, that there are many thousand people who are conscientiously curtailing the use of light and believe that they are thereby doing their best in this conservation of fuel movement. Light should not be used extravagantly but, as stated above, it is very easy in approaching this subject from the heating end, to effect a saving many times greater than would result with a 100 per cent. saving in light.

WM. J. SERRILL: In reading Mr. Millar's very interesting and valuable paper, I have been struck with the wide difference between the estimates made by the experts he consulted, as to the amount of lighting that is needed in normal times, as compared

with their estimates of what is needed in war times. These estimates place the proper amount of lighting in normal times at 73 per cent. higher than at present, while in war times they place it at 3 per cent. lower than at present. I am wondering whether the estimators in arriving at the latter figure, were not influenced by the present extreme condition of coal shortage. When these estimates were made, the coal shortage in the country was at its height. If it were believed that such a condition were to continue throughout the war, of course, a 3 per cent. decrease in lighting would not be unreasonable. But no one believes that such a coal shortage will continue, or will even repeat itself next winter. Therefore, if this table is intended to represent what should be the reduction below present lighting throughout the period of the war, I question whether there should really be any decrease whatever.

I have some sympathy with Dr. Cutler's remarks about white way lighting. While I believe that white way lighting is desirable and of advantage to any city, yet I wish it could be made more artistic than it generally is. The enormous signs that are needed in order to produce the grotesque effects aimed at are a defacement to the buildings on which they are erected, during daylight, and at night the effect is generally far from artistic. The development of flood lighting on a commercial scale permits of a very artistic illumination of the facades of buildings. It would be interesting to see a section of one of New York's principal thoroughfares treated with a flood of light in such a way as to make the most beautiful effect by night, and to produce the least possible defacement of the thoroughfare by day.

It will be noticed that Mr. Millar has confined his paper to electric lighting. He has told me that the time at his disposal in the preparation of the paper was too short for him adequately to consider gas lighting. As gas lighting is largely confined to residences and to the interiors of stores and industrial establishments, it is not materially affected by the rulings of the Fuel Administration, and consequently, there is little impropriety in omitting it from the discussion. Roughly speaking, about 4,000,000 tons of coal per year are consumed in gas lighting.

R. E. SIMPSON: I have made an effort to find out whether or

not the order of the Fuel Administration and the agitation for light curtailment has had any effect on the accident rate, but reports are coming in slowly. There were one or two instances which may or may not be symptomatic. One man, in whose hands is placed the direction of a score of mills, evidently impressed by the press agitation for light curtailment, sent out instructions to cut down all unnecessary lighting. Some of the foremen in their endeavor to carry out the manager's plans shut off the lighting of the stairways, passageways, and other unfrequented places about the mills. The result was an appreciable increase in the accident rate, principally from falls, at the unlighted sections. This policy was brought to a climax when one workman was caught by a revolving shaft near the floor in an unlighted section and was killed. It is not difficult to analyze the lesson to be drawn from this accident. By shutting off the light at this point probably 5 pounds of coal at the most was saved daily. This may be placed on the credit side. To offset this, however, one man's life has been sacrificed. His dependents will have a hard struggle for existence and may be a burden on the community. The nation at a time of vital need has lost one of its producers. This, then, is the price paid for saving a few pounds of coal a day. The compensation to be paid for that one accident will be sufficient to pay the lighting bill for the entire mill for a period of 17 months. That is a form of saving that is short-sighted and of course represents false economy. It seems advisable then to give due consideration, not only to the item of saving, but also to the ultimate price to be paid before light curtailment is enforced.

S. E. DOANE: The lighting business of this country has increased more rapidly this last fall than ever before in the history of the business. In other words, in spite of the fact that we are trying to economize on lighting, the building of ship yards, the running of factories at night, the building of those thirty-two big cities in which many of our soldiers live under electric light for the first time and many other things have tended to increase the use rather than decrease it. I don't know how we can better serve our industries than to make that fact very clear, that the solution of our problem does not lie in curtailment of lighting,

but to the efficient use of more light than we now employ. We can look forward to no saving of coal, but on the contrary to a greater use of coal than ever before in our history for lighting. Of course we want to conserve all the energy that we can by efficient lighting for we shall need all we have. Consequently it is up to us to save light all we can. But I think that the Illuminating Engineering Society ought to make it very, very clear that the methods of the food conservation departments and commissions should emphasize that the place to save fuel is in the home, that the services of the women who have been so patriotic in their Red Cross and their food conservation efforts, should be enlisted to save fuel. We, as engineers, ought to offer our services to the community to bring home to every individual in it the fact that the saving of fuel must be undertaken as a national duty.

WALTON FORSTALL: A lower temperature might easily be maintained in office buildings with a certain amount of inspection. If instructions should be sent out to the managers of office buildings that they should not be heated to more than 67°, much more fuel could be saved in this way than by curtailing lighting. In most of the office buildings and homes with which I am familiar the waste of coal by overheating is tremendous.

W. H. GARTLEY: In talking about the educational idea—educating the people—I was present at a conference in which Dr. Garfield made some statements in the earlier part of his tenure of office, and when the question of curtailment of display electric light sign lighting was in his mind, the question arose whether it would not be a good thing to reduce the amount, because, as he said, of the psychological effect. Dr. Garfield at that time had an idea that the amount of coal that was used in display lighting was larger than he afterward found it to be, on the statement of men who were at least as reliably informed as anyone could be; and his predecessor, Mr. Peabody, also made the statement before, that there was going to be a very large amount of saving due to the curtailment of sign lighting. At that time, the men who were present and were acquainted with the electric light field, made an estimate of about how much that would amount to per family per year. It was something like 4 pounds

of coal to each family, if all the display sign lighting was eliminated. Then, I think afterward they rather increased that perhaps 50 per cent. But the psychological effect was that a great many people who thought they knew, had to modify their views as to what a tremendous amount of energy was used in sign lighting. They did not realize that these bulbs were very small lights. My thought was in asking Mr. Millar whether there had anything come up in New York as to the result of this sign lighting. New York City has it in accentuated form. The fact of the matter is that this severe winter that we have gone through has apparently brought home to a very large number of people, who have been living in the cities, the necessity of reducing the expenditure for lighting, and from the data that we have in connection with the gas business, it appears evident that they found some means of doing it.

C. O. BOND: I think that Mr. Gartley perhaps had in mind the same thought as I had when he inquired for information on the psychological effect of light curtailment. It will be very difficult to get into the mind of a man who actually has no coal in his own home and cannot keep his family warm, that garish sign lighting—demonstrating bottles of beer pouring out, and so on—should go on during a time of shortage of fuel. Those contrasts are bound to be noticed. People must conclude that there is a waste of energy and fuel in a case like that, and while they are likely to regard the energy waste as a great deal more than it really is, still the lighting companies ought to hold themselves as exemplars in time such as these, and reduce clearly unnecessary lighting in an attempt to meet the Government's requirements and as an incentive to others to do the same thing.

On page 123, Mr. Millar has offered to me a very striking suggestion, where he speaks of recent tests made in a machine shop in Chicago, where, by increasing the lighting intensity from 4 to 12 foot-candles, the efficiency of operation has been increased by something like 15 per cent. If there is any place in industrial work to-day where the man works at a disadvantage, it would be in a place where his entire surroundings are black and illumination is very, very poor. That is exactly the condition we meet with in our coal mines. Therefore, if you can work out some

scheme by which your mine lighting can be made three or four times better, you can get perhaps a 15 per cent. increased coal output amounting to millions of tons!

Regarding the propaganda for fuel conservation in the home: You send a tag around to my house to be tied on the shovel, but the person who uses the shovel may not know much about the economies possible in operating his heater. You go down to shovel on coal; open the draft; and later on, when the fire burns lower, you put on more coal, and so it goes on all day long. Have you shown them the proper position of the draft, etc., through the public press or pamphlets, and suggested to them where to place their thermometers, and whether the cellar windows are to be kept open or closed? All that sort of thing is important information to give out and to use toward accomplishing the end you seek.*

WM. LEROY ROBERTSON: I have had the pleasure of making a study of the effect that "daylight saving" will have on the electric lighting in Philadelphia, and I might say that if the clock is advanced one hour, the net saving in the lighting load alone will be about 6 per cent.

If a curtailment in electric lighting of 3 per cent. will save 340,000 tons of coal a year, as pointed out in Mr. Millar's paper, and assuming that the effect of "daylight saving" in Philadelphia is representative of the effect throughout the country, then the 6 per cent. gain by "daylight saving" will save an additional 680,000 tons a year for all electric lighting. This is based, however, on adopting "daylight saving" the year around; if adopted for six summer months only, then less than half of this amount, or about 270,000 tons would be saved, since lighting loads are not as large in summer as in winter.

Another important point relative to the effect of "daylight saving" is the reduction of the peak load on the electric light plant to the extent of probably 15 per cent. at least. This reduction will occur only should "daylight saving" exist during the winter months. This means the liberation of an equal percentage of plant capacity, which will be immediately available all over

* It is interesting to comment that about 10 days later, in Philadelphia, such a campaign of information and instruction began.

the country for industrial power loads, which during war times, is a valuable governmental consideration. To obtain such capacity by erecting new plant equipment requires considerable time and consequently involves serious delay when considering governmental work.

GEO. A. HOADLEY: One of the savings mentioned in the paper is that resulting from reducing the temperature of our rooms from 70° to 69° . This saving is stated to be 3,000,000 tons. The point I want to make is that the difference between 70° and 69° is so little that no one could perceive it. If the difference of only 1° is going to make these 3,000,000 tons of saving, why can we not better afford to cut off, say, 5° , and save 15,000,000 tons.

In regard to the matter of daylight saving, there is only a small portion of the year in which it would seem applicable to industrial occupations. Take our shortest days, for example: we light both ends of them in industrial work. The contention is that there would be a great deal of saving by shifting the clock one hour. We could accomplish practically the same thing by equalizing, or more nearly equalizing, the amount of time given before and after the noon hour, assuming that we give an hour at noon, or less. If we would work earlier, I do not know why it should be necessary to change the clock.

G. B. REGAR: I do not approve of a change in the intensities of illumination at this time, either increase or decrease. I think that the most efficient lighting, however, should be favored in the industrial plants, and, of course, an increased intensity where necessary; but if a true economy can be practiced in the homes, office buildings, hotels, theatres and stores, I feel that it should be carried out, and as stated before, the sooner we all co-operate to win the war, the sooner it will be over and business will be back in the condition that it belongs.

H. CALVERT: Judging from the title of the paper, one would infer that Mr. Millar was speaking of lighting from all sources. Actually, he has confined his figures entirely to electric lighting. Therefore, to the 340,000 tons which might be saved from electric lighting should be added the saving which it may be possible to effect in gas lighting.

E. B. MYERS: Mr. Calvert has asked what annual saving in coal could be made by a reduction in the amount of gas lighting now being used in this country. Data published last year by the U. S. Geological Survey show that in this country there is used, each year, in the manufacture of gas, that is, gas marketed and sold, a total of 28,000,000 tons of coal and coke. This quantity includes anthracite and bituminous coal and coke. There is, however, returned to the market for sale, a total of 17,500,000 tons of coke, which is the equivalent of more than an equal weight of coal. Subtracting this 17,500,000 tons from the total of 28,000,000 tons, we arrive at a net figure of 10,500,000 tons used up in the manufacture of gas. It has been estimated by various authorities that 30 per cent. of the total quantity of gas manufactured is used for lighting purposes; 30 per cent. of the 10,500,000 tons, or 3,150,000 tons of coal are used for gas lighting. Therefore, if we reduce the quantity of gas lighting by 15 per cent., we conserve 473,000 tons of coal per year, and if we reduce the quantity of gas lighting by 3 per cent., we conserve 95,000 tons of coal per year. The ton used in these remarks is the short ton.

ARTHUR J. ROWLAND: There is an especially important problem of coal conservation locked up in the light supplied by isolated industrial and manufacturing plants. Here the economy in the use of coal is notoriously bad; and yet that fractional part which is used to supply the energy for transformation to light is very hard to get at; it is sometimes counted as a by-product in the heating of the buildings. Is this the place to consider the small dynamo plant and its inefficiencies? The thing of importance to the country to-day is not what is the cheapest way to get light, for that may indicate the use of an inefficient isolated plant, but how to save coal. This is a very different question.

UNIT RASIN: I have paid a great deal of attention to lighting, and I want to say that I think the attitude that Mr. Millar has taken in this paper called for a good deal of courage, because I think that the popular mind is against his theories as expressed here. The whole intent of our sign lighting is the spectacular; its appeal to the eye. When we think of something to cut out, our minds fly right to the spectacular but innocent sign. I do

not think it is the intent of this paper to minimize this possible saving of several hundred thousands of tons of coal, but rather to correct the popular impression that the small curtailment of lighting is going to make for a tremendous saving of coal. Don't let us lose sight of exactly what Mr. Marks has said (following), and what Mr. Millar has pointed out; that we must not diminish but should increase the intensity of lighting for industrial use. We have had a most difficult time in making manufacturers understand the necessity for more light. Manufacturers are beginning to see the necessity of really having adequate light in order to increase production and decrease spoilage. I think we can take it for granted that there will be no misunderstanding as to the necessity and sincerity of purpose in recommending certain increases in lighting at a time when everybody is doing everything they possibly can to save coal.

F. N. HAMERSTROM: The suggestions made for saving coal by curtailing heating and by improving the combustion of heating appliances are valuable and will no doubt be appreciated by the Fuel Administration, but it also expects this Society to cooperate by advocating the saving of coal where possible for making light. Every one seems willing to agree that in these times we need *more* light, and that there is little opportunity to curtail. Our problem is to meet the need for more light with less coal.

Mr. Millar states that substituting modern lamps for less efficient lamps in use will effect a saving of coal. This point might stand more emphasis than has been given it. Carbon filament electric lamps require much greater percentage of current than the more modern tungsten filament lamps, and the customer is slowly becoming educated to buy the more efficient types. Notwithstanding all this, we are told that 26,000,000 wasteful carbon (or Gem) filament lamps were made and sold last year. Without curtailing light, coal might be saved by inaugurating active campaigns against carbon lamps.

A tremendous population is dependent upon gas for illumination. If all gas light were produced by means of efficient mantle lamps in place of partly by open-flame gas burners, a big saving in fuel would be effected. A U. S. Government report entitled

"Artificial Gas and By-products in 1915," by C. E. Leshner, states, in rounded off figures, that 284.4 billion cubic feet of artificial gas was manufactured in that year, and that 30 per cent. of this, to be conservative, was used for gas lighting. A paper recently read before the Indiana Gas Association gives the proportion from 30 to 40 per cent. Several important gas companies have estimated 45 to 50 per cent., and one company has estimated that 53 per cent. of the gas it makes is used for light.

The saving which would result in replacing open-flame burners with mantle lamps could not be estimated accurately, as there is little or no data available. The U. S. Bureau of Standards is authority for the statement found in Circular 55, "Measurements of the Household," that from five to seven times as much gas is used where open-flames are depended upon for light. Granting that there may be many more mantle lamps in existence (a question open to doubt), it does not seem unreasonable to calculate that the open-flame burners in use consume at least over half of the amount burned for light, or, in other words, one-sixth of the total gas manufactured, or 47.4 billion cubic feet.

Using U. S. Bureau of Standards' minimum for the calculation, efficient mantle burners would produce as much, or more, light with one-fifth of the gas; thus saving four-fifths of the 47.4 billion cubic feet estimated consumption of open burners in use, or a saving of 38 billion cubic feet of gas, and all the coal and oil required to make it.

Taking into consideration changed conditions since Mr. Leshner's report of 1915, comparisons would be still more favorable to good mantle lamps, for it is only reasonable to assume that unless open flames are displaced, the gas consumed by such burners will after 1917 increase fully one-third on account of the reduction in open-flame candlepower of about 25 per cent., due to lower candlepower values already allowed by commissions in many localities and contemplated in others.

Adhering to the previous method of calculation, without making any allowance for natural increase of the business which may have taken place since 1915, an annual saving of 57.7 billion cubic feet would be the result.

An aggressive campaign to install mantle lamps will enable

the gas company to give people a great deal more light, which conforms to Mr. Millar's ideas as to what is really needed, and will, at the same time, effect a very considerable saving in gas, coal and oil, requested by the Fuel Administration.

L. B. MARKS (Communicated): I wish emphatically to endorse the conclusions reached by Mr. Millar and to express my appreciation of the painstaking work he has done to enlighten the community on this very important and timely subject of discussion. Both the author and the Society are to be congratulated on presenting at this critical time an authoritative treatise that should serve to guide the Federal administration in making rulings relating to the curtailment of lighting.

Industry in general is absolutely dependent upon artificial light for a large percentage of working hours per year, from the triple standpoint of getting out the product, minimizing spoilage and minimizing accidents. For well-known reasons, it is difficult to determine quantitatively the effect of lighting on these three points, but such quantitative determination is not important, in the present emergency, because every up-to-date manufacturer has been convinced by experience that he cannot afford to cut down his lighting without sacrificing production and increasing spoilage.

There is one item upon which I should like to lay further stress in this discussion, and that is the serious aspect of lighting curtailment as related to accident prevention in the industries.

In the factories, mills and other work places which I have served professionally during the past twenty-five years, the importance of good light as a factor in accident prevention has been taken as a matter of course. This covers not only good lighting facilities, but the maintenance of good lighting throughout the working period.

I hold that in the present exigency, general curtailment of light in the industries would be disastrous, and that on the contrary, there is real need of increasing the light and of utilizing it to better advantage.

I estimate that in the State of New York approximately 50 per cent. of the factories, mills and other work places are still

illuminated by the antiquated system of local illumination, notwithstanding the fact that it has been conclusively proven that a good general illumination of the shop is necessary from the triple standpoint mentioned above. This same situation with regard to prevalence of strictly local lighting holds with comparatively few exceptions for most of the eastern states. I cannot speak for the West.

One result of localizing the illumination on the machines or work-benches while leaving the aisles, passageways, etc., unlighted except for stray light from the local lamps above referred to, is that the accident rate is increased.

It is commonly supposed that most accidents in shops occur at the machines or work-benches. Investigation of this subject has revealed the fact that approximately two-thirds of the accidents that occur in shops take place not at the machines or work-benches, but in transit from one part of the shop to the other, or in approaching or leaving a machine or work-bench.*

I regard this matter as of the greatest importance in the present emergency because a curtailment of light would unquestionably result in a lessening of the general illumination required for safety. By general illumination, I mean the illumination over the whole working floor area as distinguished from the illumination of the machines or work-benches. As stated above, the general illumination by artificial light is now inadequate in a large proportion of factories, mills and other work places. It is, therefore, to be expected that an increase in accidents would follow the curtailment of lighting under present conditions.

If for any reason a curtailment of lighting in the industries were ordered by the Government, steps should be taken to inform the industries of the additional danger of accidents involved in lessening the general illumination.

The standards for safe illumination are available in the Code of Lighting Factories, Mills and Other Work Places, published by the Illuminating Engineering Society, and in the Codes of Pennsylvania, New Jersey, Wisconsin and Ohio.

* See "Industrial Accident Prevention;" statement by Mr. Beyer of Massachusetts Employers Insurance Association. Also *Bulletin of the Industrial Commission of Wisconsin*, Aug. 4, 1915. Also *Economic World*, Sept. 18, 1915; statement of Mr. Hansen, Secretary Workmen's Compensation Service Bureau.

A. L. POWELL (Communicated): Mention has been made of the psychological effect of lighting curtailment. The general impression is that this is a beneficial effect. One phase of the question has been very forcibly brought to my attention and leads one to wonder whether the game is worth the candle.

As the result of an extended, well-applied propaganda on the part of the Illuminating Engineering Society, manufacturers of lamps and lighting equipment and the managements of industrial plants have begun to realize the importance of correct lighting. This educational work has been a slow, uphill proposition, and was just about beginning to bear fruit. Witness the industrial lighting codes adopted by some states and under consideration in a number of others.

The nature of my work leads me to call on many manufacturing establishments. A few months ago it was not extremely difficult to convince the shop superintendent that good lighting is an asset rather than an unavoidable expense. Since wide publicity has been given to the apparent necessity for curtailment of lighting a very different attitude is encountered. You have an initial impression to overcome. Your problem is first to overcome this rather than to consider what should be installed properly to light the shop. If you argue that the saving in reality is ridiculously small you seem unpatriotic in view of the warnings sent out by the coal administration and others.

This situation is far more serious than it seems. I recall inspecting one shop which was formerly excellently illuminated by medium sized efficient lamps with well-designed reflectors. To my amazement these lamps had been removed, a considerable amount of additional wiring installed, and bare inefficient lamps had been hung directly in the line of view over each machine. On inquiry as to why these changes were made, I was informed that the management was very patriotic and desired to do everything to help the Government in its emergency. The plant electrician had a false impression that it was essential to hang the lamps near the work and had removed the reflectors because, as he stated, "they absorbed light." These conditions need no comment.

Everyone interested in better lighting cannot help but deplore such an unfortunate situation as we now find in industrial plants.

We should go on record in regard to this and do our best to overcome the erroneous impressions which have been created.

DUGALD C. JACKSON (Communicated): The standards of illumination before the days of coal stringency were gradually coming toward a reasonably satisfactory figure, but in general they were not as high as they ought to be (omitting the consideration of war conditions) in these times of highly efficient light production. Suitable artificial illumination is one of the great factors in the maintenance of our characteristic civilization. For these reasons we should expect something of an increase in the amount of illumination as compared with the past, if it were not for the war times.

The way to abate unessential illumination is to abate decorative and display lighting, lighting on the streets not necessary for aid to the police and safety to pedestrians and drivers, and to urge that all other lights shall be turned off when not actually in use. For instance, in the ordinary home, lights will be left burning merely as a matter of convenience, or as a matter of providing a pleasant appearance. This is all very well in ordinary times, but in these times lights should be *turned off whenever not actually needed for a specific purpose*, and then turned on again when the need again arises.

F. A. VAUGHN (Communicated): There are many greater possibilities for saving substantial amounts in coal through propaganda and education in connection with fuel engineering, combustion engineering and steam engineering, than can be realized through any savings that can be effected through illuminating engineering, except, of course, the savings that come from more efficient lighting rather than less lighting.

My own idea of this matter is, that I would like to see a nation-wide campaign against the tremendous wastes in coal, in the coal pile, in the boiler furnaces, and in the live and exhaust steam utilization, and would rather postpone any substantial curtailment of lighting, because of the season of the year and the comparatively small effect that we can have on the total actual consumption of coal before next fall. As the days are getting

longer, the saving until then would be comparatively small (even smaller than Mr. Millar's figures show), and I would, therefore, suggest postponing action on this item until fall at least, and curtailing then, if necessary; in the meantime concentrating on larger items.

In war time we are in greater need of our already inadequate industrial, school, home, and street lighting than ever. Policemen, soldiers, fathers, and other protectors are at the front. Speeded up production is more urgently necessary, and there is therefore apparently little room for curtailment of lighting in places which are the source of this production.

Of course, if any curtailment seems absolutely necessary, I would advise the cutting down of display lighting and other "ornamental" kinds of lighting, but not any of the lighting in spaces where actual eye-work is carried on, especially if it affects in any way the production of munitions or other essentials.

ARTHUR J. SWEET (Communicated): Light is primarily to be considered as a tool in industrial, clerical and household activity, and as a protective agent in exterior lighting, corridor and stair lighting, etc. Where intelligently so used, its curtailment represents waste and injury to the nation in its present crisis rather than economy. It can no more be justified than could the use of inferior tools in industrial work.

Current consumption standards are occasionally too high in lighting service which has not been designed by competent engineering ability. Illumination or lighting standards are so seldom too high, however, that the few cases where they are too high can be ignored.

The only exception to the above generalizations is, in my opinion, in the field of advertising lighting. I am heartily in accord with the extensive curtailment, possibly even the 100 per cent. curtailment of advertising signs and possibly with some curtailment of show window lighting. I am in favor of some curtailment of ornamental lighting, but not to any point which affects the utility of the service to such degree as to involve any appreciable decrease in the safety from collision or the safety from attack afford.

Beyond the above points, I believe the curtailment of lighting

would be contrary in every way to our national interests. Rather, the emphasis should be on improved lighting standards, particularly in industrial lighting. Of course, lighting installations should be laid out with adequate application of our engineering knowledge, so as to avoid unnecessary wastes; but the national interests will better be served in my opinion, by improved lighting, especially in the industrial field, which improved lighting will, on the whole, involve the expenditure of more rather than less energy. In office and general clerical work, there should be on the whole no decrease in energy employed for lighting, though the desirable increase is not as great as in the industrial field. In home lighting, economy in not burning lamps in unused rooms should be observed, but it is now generally so observed, and there is therefore very little opportunity for increased economy in this direction. The total quality of the service provided in the home should not be decreased.

I feel that the illuminating engineering profession is failing to rise to its opportunities at this time in emphasizing, in a way which will reach the consciousness of practically every citizen, not that lighting should be curtailed (except perhaps advertising lighting), but that wastes of energy in lighting service should be eliminated by the application of well-established engineering principles and that, in addition to the energy made available by such curtailment of wastes, the total consumption should in many cases be increased in order to make more effective the man-power of the nation both in productivity, reduced spoilage, and reduced impairment of the eyesight which is vital to future productivity.

P. S. MILLAR (In reply): The paper has served one of its purposes in that the discussion which it has elicited has covered the subject quite thoroughly. Among those who have participated there is practical unanimity to the effect that we should all co-operate to save coal where practicable through the elimination of waste in lighting, and possibly, if the emergency warrants, through curtailment of lighting. It is agreed, however, that our utmost efforts will effect only a very small saving in coal. The country must look elsewhere for the larger savings in coal which have to be accomplished. The representative character and diver-

sified view-points of the men who have contributed to this discussion bear testimony to the validity of this conclusion.

There was some adverse comment on Bulletin No. 5 of the Committee on Coal Conservation of the Chamber of Commerce of the United States which is appended to the paper. This Bulletin is included because it points out five ways in which coal can be saved through attention to artificial lighting practice. We are all in accord in our desire to effect such savings. The Bulletin can be made useful in this effort. I fully agree with criticisms of the Bulletin on the score that it devotes only two paragraphs to saving coal through attention to building heating practice, where large savings can be effected, while devoting five paragraphs to lighting where but small coal savings are possible. We desire to join with the Chamber of Commerce Committee in urging elimination of waste through lighting, while seeking to place various forms of waste of coal in their proper perspective, to the end that the largest savings may be effected as a result of directing effort into channels of greatest potential saving.

Mr. Gartley has asked for information on the psychological effect of electric sign extinction in New York City. On this point I have nothing but my personal opinion which is worth no more than that of any other observer. It is my opinion that the effect of occasional extinction has been good. It is proper and helpful to remind the people that we are at war, and that their efforts must be directed toward sober achievement. I have understood, however, that the purpose of sign extinction has been to save coal and not to accomplish any psychological effect. As a coal saving measure I have seen the statement attributed to the Fuel Administration that the extinction of all sign lighting in the country two nights per week in the course of a year is expected to reduce the consumption of coal by about 250,000 tons.

Some comments have indicated that the paper shows little respect for small savings. I do not want to create that impression. The public, however, has gained the impression that large coal savings are to be effected through lighting curtailment. The newspapers foster this idea. As recently as the first week of January, the Fuel Administration was responsible for the statement that "there is an enormous waste of coal due to extrava-

gant and reckless use of electric lighting." The amount of attention devoted to coal saving through lighting curtailment by the Fuel Administration, the public press and the public in general, is in my judgment out of all proportion to its importance as a coal saving measure. It has seemed to me therefore important to emphasize the fact that the saving of coal through curtailment of lighting is relatively insignificant. In devoting an undue proportion of effort toward lighting curtailment, there is danger of neglecting to accomplish much larger savings in other directions.

For the many favorable criticisms upon this paper and for the appreciative comments of a number of the speakers I extend my thanks.

THE VALUE OF ILLUMINATING ENGINEERING TO THE GAS INDUSTRY.*

BY ROBERT FRENCH PIERCE.

The activities of the public utility as directly affecting the consumer are two-fold—engineering and commercial—the rendering of service and persuading the consumer to purchase the service.

The relative scopes of engineering and commercialism have never yet been defined to the entire satisfaction of many individuals, and while the line of demarcation is at certain points indiscernible, it will be worth while to attempt, at least, a more workable and practical definition than has yet been offered.

Engineering, as defined by Tredgold and accepted by the public in general, is the controlling of natural forces for the benefit and service of mankind. Anything which has directly to do with transforming, modifying and utilizing the heat of coal, gas or the potential energy of the waterfall for heat, light or power comes within the province of the engineer. The manner in which the transformation should be accomplished, the form in which, and the conditions under which, the transformed energy should be delivered to the consumer, and the manner in which the final product—light, heat or power—should be used by the consumer, are purely engineering problems, concerning which no one but the engineer is competent to exercise authority. In exercising this function the engineer must co-ordinate and effect compromises among many and diverse fields of knowledge and endeavor. In the case of lighting he must have due regard for the facts obtained and set forth by the psychologist, physiologist, ophthalmologist, photometrist, physicist and chemist and still observe the usages and practices which govern all activities into which economic considerations enter—legal and financial. Engineering is after all, simply the common-sense intelligent way of weighing

* A paper prepared under the auspices of the National Commercial Gas Association, for the 1916-17 Correspondence Convention of the Illuminating Engineering Society, and circulated among members of the Society and others who were thought to be interested.

This paper was also presented by the author before the New York Section November 8, 1917.

and balancing these factors, in order to secure the greatest ultimate common good, and existing engineering practices and methods do exist simply because they have been found the best and most effective means of securing these results.

The object of commercial activities is to persuade the customer that the service provided is sufficiently desirable to justify the price asked for it and to maintain those pleasant relations between the company and the public upon which the continuous and increasing inclination of the latter to purchase the product of the former may be maintained indefinitely.

Between intelligent men who understand their limitations there can be no great conflict of opinion as to the proper spheres of engineering and commercialism. It is only when one or the other attempts to extend his jurisdiction beyond his legitimate territory that friction arises. When the engineer restricts the expansion of the business by emphasizing economy at the gas house to such an extent that the service suffers, and when the commercial man fails to exercise his positive functions as a seller of service, and retrogrades into the merely negative of an order-taker, selling merely what the consumer *thinks* he wants, the business suffers.

Thus the engineer is a maker of service—the commercial man a seller of service. But what is service? Does it consist solely in maintaining courtesy in the complaint department, and in dispatching a fitter by motorcycle within three minutes of a telephone call indicating a gas leak? A great many people appear to think that the essentials of service consist in just such things as these.

Service is, whatever is the object of the consumer's purchase. Rendering the service with an accompaniment of promptitude and amiability does embellish the service, and these embellishments are useful and desirable accordingly, but they do not augment the value of the service to the consumer. These things are merely the garnishings and decorations of service. They make it look and so to speak taste better, but add little nutriment.

A tailor may use the best of clothes, the finest of linings, may employ the most courteous of salesmen and the fleetest and most resplendently uniformed of messenger boys to deliver his goods; but unless the clothes fit the purchaser, he has bought 99 per cent. paprika and 1 per cent. substantial service.

The service which a lighting company renders to its lighting consumers consists of good illumination—adequate, comfortable, attractive, dependable. What shall it profit the consumer if he purchase a lamp from the most affable salesman in the world, has it delivered in the speediest delivery car, and is assured instantaneous and courteous treatment of all complaints if, after installation the light is glaring or inadequate, or improperly distributed? He has not bought service, as he thought and had a right to think. He paid for service and got a misfit. It is quite likely that he is not sufficiently critical to appreciate the fact, but in this age of rapid dissemination of popular information, a business founded upon the ignorance of the public is to say the least precarious.

Of course it is quite impracticable to so effectively supervise every installation as to ensure good results in all cases, and if examples of bad lighting due to the customer's ignorance were by any means infrequent, the practice of lighting companies in this respect would perhaps be above criticism. But at least 90 per cent. of all artificial lighting is done in a way that reflects discredit upon the illuminant employed, upon artificial lighting in general, and yields to the user but an insignificant fraction of the service which he has a right to expect. A large proportion of these unmitigated atrocities are installed at the suggestion and by the advise of salesmen whom it would be comparatively easy to control in the interest of the consumers eyesight if there were any inclination to do so. Too often so-called "commercial" considerations—which are really the intrusion of commercial factors where they do not belong—are responsible. One example, which is perhaps typical, will illustrate this.

Not long since a commercial manager asked the assistance of a lighting specialist in securing a contract for lighting a factory. The proprietor of the factory had become suddenly affluent through "war orders" and had expected to scrap his open gas flame lighting and substitute electric lighting. The conditions made it necessary to use artificial light all day. The work was exacting in nature, and the operatives suffered to some extent, at least, from the high temperatures prevailing at the machines. The proprietor stated as the most important requirements in his estimation: the reduction of heat and the furnishing of a light "easy on the eyes." Suggestions were made covering the use of a stand-

ard gas lamp with a standard factory reflector, the lamps being spaced to provide uniform illumination, and placed 12 ft. above the floor to reduce discomfort from radiant heat beneath the lamps. When this suggestion reached the commercial managers desk it was rejected as "impractical" on the following counts:

1. He had always used "arc-lamps" in factory lighting, and "guessed" they were good enough in this case.
2. He had a hundred second-hand arc lamps from a rental contract he had just lost, and it would be a crime to spend money for new lamps.
3. He did not have the recommended reflectors in stock, and didn't think reflectors were any good anyhow. At all events the "arc-lamps" had a sort of reflector attached that he "guessed" was good enough.
4. They had always hung lamps 8 ft. from the floor. The additional height would make some extra work for the trimmer and he "guessed" it didn't make any difference anyhow.

The commercial manager installed the lamps of his own choosing according to his own ideas, *and fitted them with clear globes* (which were more "practical" it seems.) Three months after the installation was thrown out because employees complained of the "heat and glare from the lamps" and the building wired for electric light.

The conclusions relating to illuminating engineering which the commercial manager drew from this incident are "illuminating" to say the least. In discussing the subject some months afterward he relieved himself of the following:

1. There was no need for special training in illumination. He could teach a salesman all the "practical" points in an hour's conversation.
2. All engineers, particularly illuminating engineers were "impractical" and did not appreciate the necessity for "commercialism."
3. The public was so hopelessly prejudiced against gas lighting, even though it *was* better, that it couldn't be sold.

Now the attitude and the frame of mind evidenced by the foregoing are by no means ubiquitous, but they are sufficiently wide spread and influential to constitute a very important—in fact *the most important* menace to the gas lighting industry to-day. It is safe to say that at least one-half and probably two-thirds of the gas-lighting business which has been lost to competitive illumin-

ants, has been lost as a direct result of this attitude, and could have been retained through a more enlightened view of commercial problems.

That there has not been an entire lack of prophets in the gas industry, through most of the prophets have entirely lacked disciples, appears from some of the earlier transactions of Gas Associations. In 1887 Mr. E. C. Jones presented before the American Gas Light Association a paper entitled "The Relation of Intensity of Light Visual Perception." In this paper he said "It may be said that the physiology of vision is not pertinent to the gas business which we are here to discuss, yet it bears the same relationship to it as the judge on the bench to a criminal on trial. To it we must plead our cause and *on its judgment depends the success of our industry*. A large proportion of the companies manufacturing gas at the present time style themselves *gas light* companies—that is, they morally carry the gas beyond the meter to the burner of the consumer." He also very clearly explained why it is that quantity of light and illuminating effect as appreciated by the eye are not proportional to each other.

In the same year and before the same association, Mr. A. C. Humphreys read a paper on "Illumination *vs.* Candlepower" which stated the fundamental physical basis for illuminating engineering. In 1899 Mr. F. N. Morton presented before the same association the results of a series of subjective estimates of various lighting conditions—indirect lighting (by gas, by the way) being among them. In discussing this paper Mr. N. W. Gifford said "Until recently perhaps, after we had made our gas we thought there was nothing further for us to do but let our customers get the benefit from it. It seems to me it is a step in the right direction to *tell our customers how they can get the best effects from the light we are selling them*." Mr. F. B. Wheeler said "These problems of interior illumination are *the most important that gas engineers have*." He also called attention to some work which represented the beginnings of illuminating engineering in Germany, and cited an editorial in the "Engineering Magazine" calling gas and electrical engineers to task for their neglect of this field.

These incidents are cited to show that illuminating engineering far from being a mushroom upstart possesses all the dignities and

prestige which are tributary to age. The estimation in which it has been held by some of the most prominent men in the industry, as witnessed above, entitle it to the most careful consideration.

There are three obstacles in the way of gas companies who wish to give real lighting service through the medium of applied illuminating engineering. The first is the widespread opinion among commercial men that engineering is an activity circumscribed by test tubes, precision instruments, curves and mathematical formulae, and having no relation whatever to the practical application of gas. The second is the knowledge that the gratuitous offering of an illuminating engineering service in connection with the service of gas would entail at least some additional expense, not directly recoverable from the consumer nor obviously compensated for by saving in some other direction. The third is the fear, based upon nothing in particular, that such an innovation would be "impractical"—whatever that may mean.

It is difficult to understand how the first attitude of mind can exist in this age of scientific progress. Practically all of our modern advancement in all that makes for material welfare is the direct result of an increasing application of scientific facts and methods to commerce and industry, and the governing of these activities in conformity with engineering practice. If the object of the public utility be "public service" it is difficult to see how engineering, which is the practical way of determining and rendering service, should not be utilized to the fullest extent.

The fear that the improvement of lighting service by the application of illuminating engineering, might fail to be ultimately profitable is even less comprehensible. The gas company is not a philanthropic institution, and the value of illuminating engineering to the gas industry obviously rests upon the importance of the gas lighting business. There has been a disposition in some quarters to minimize the importance of this department, and to view the fuel field as the most promising subject for exploitation. Not a few individuals are of the opinion that it is best to abandon, or at least to lose by default, a business which energy and combativeness are required to hold in the face of competition, and to devote all sales activities to fields in which competition of an effective sort does not and presumably cannot exist. There is no gainsaying the truth of the adage that "He who fights and runs

away will live to fight another day" and the easiest path doubtless lies in the avoidance of competition with its accompanying financial and mental strife, and the seeking of virgin fields from which our electrical friends are fenced out by a high if not insurmountable barrier.

The gas lighting business is, however, so inextricably connected with the domestic fuel business that it is doubtful if a separation of the two may be effected without calamitous results. At the present time it is roughly estimated that 30 per cent. of the artificial gas sold is used for illumination, 50 per cent. for domestic fuel and 20 per cent. for industrial fuel. These estimates are not based upon actual measurements, nor upon comparisons or calculation having a valid and substantial basis, and must be taken as including a certain modicum of personal predilection. Undoubtedly many gas companies which have received rather rough handling in lighting competition would like to believe that this business is of small consequence anyhow, and this inclination colors the estimates to a certain extent. Statistics of lamp and mantle manufacture indicate that the estimates for gas used for lighting are to say the least extremely conservative and probably much too low. For rough approximations $33\frac{1}{3}$ per cent. will be a satisfactory figure and one that will not err in the direction of liberality.

What may for lack of better designation be called the typical *good* domestic gas consumer, purchases annually say 35 cu. ft. of gas at \$1.00 per cu. ft., the gas company's revenue being, therefore, \$35.00.

The cost of serving this customer may be divided as follows:*

- I. General cost.—Expenses and disbursements which are independent of the number of customers or of the amount of gas consumed.

(a) Interest and dividends.....\$2.98

(b) Operating expense 6.15

— \$9.13

* The figures are based upon those presented as a consolidation of those of a half-dozen companies on the Atlantic and Pacific coast in the Report of the Committee on Differential Rates. N. C. G. A. 1914. On account of the wide variations in the distribution of expenses resulting from differences in local conditions, and the recent great advance in cost of material and labor, these figures cannot be applied to any particular situation, nor to recent years.

2. Customer Cost.—Expenses and disbursements which are proportional to the number of customers, but independent of the amounts of gas consumed.	
(a) Interest and dividends.....	\$3.76
(b) Operating expense	3.55
	<hr/> \$7.31
3. Demand Cost.—Expenses and disbursements which are proportional to the maximum rate at which the customer may consume gas, but independent of the total amount consumed per year (estimated on the basis of 22 cu. ft. per hour, maximum one hour demand).	
(a) Interest and dividends.....	\$5.24
(b) Operating expense	4.57
	<hr/> \$9.81
4. Service Cost.—Expenses and disbursements depending upon the amount of gas consumed yearly.	
(a) Gross cost of gas-making materials, less credit from residuals, plus manufacturing, labor, maintenance and distribution expense.	
\$0.25 per cu. ft.....	\$8.75
	<hr/>
Total	\$35.00

The above illustration is that of a consumer very near the ideal (from a revenue producing standpoint) among small domestic consumers. Any customer who, with the same maximum demand takes a smaller amount of gas per year, or taking the same amount per year demands gas at a quarter maximum hourly rate, is not only unprofitable, but is served at a loss which must be made up by an excessive charge upon customers of a more profitable sort.

If the above customer discontinues his gas lighting, the company's revenue (at \$1.00 per cubic foot) is reduced to \$20.42, and its expenditures, classified as before, appear below:

1	\$ 9.13
2	7.31
3	5.82
4	5.10
	<hr/>
Total	\$27.36
Revenue	20.42
	<hr/>
Net Loss	\$6.94

It is obvious that this relation between domestic fuel and lighting holds whether the customer is actual or prospective. The gas consumption of the average domestic consumer is insufficient to enable the gas company to make a profit unless his service includes gas for lighting.

In order to forestall criticism based upon a misunderstanding of the importance of some of the factors involved, it may be well to explain that in allocating the fixed charges and expenses incurred on account of maximum demand, the individual maxima have been regarded as coincident because no information is available concerning the magnitude of diversity factors in the service of gas. A personal opinion might be hazarded to the effect that these factors are somewhat smaller than in electric service on account of the lesser proportion of services in apartment houses and dwellings of the more pretentious sort, the occupants of which are more likely to be of irregular habits than those of houses and tenements occupied by working people whose hours for meals and recreation are quite rigidly fixed by their condition of employment.

A maximum demand of 22 cu. ft. per hour has been selected, not as being an average, but as representing a particularly good condition and one which showed net earnings (in dividends) on the service of the customer. As a matter of fact, a consumer of 35,000 cu. ft. per annum with a maximum demand of 22 cu. ft. per hour would, like the impossible hero of the Sunday School book, be quite too good to be true and certain to meet with the inevitable reward of excessive virtue—an early grave. At all events, the demand charges in the first instance comprise but about 35 per cent. of the “non-proportional” charges and about 26 per cent. of the second, so that general and customer Costs, into which the demand does not enter, are of much greater significance. All that it is here desired to show is what is perfectly obvious, and for that reason seldom realized—that in the operation of a public utility at a fixed and inflexible rate for energy there is a certain point in demand and consumption at which profit ceases and loss begins, and that in any class of business which, so to speak “floats” about this point, the retention of the most highly competitive service is of the greatest importance. The relatively non-competitively business may be regarded as

comparatively fixed. It is the easily detached revenue which determines the solidity or precariousness of the business of a given customer.

To an engineer the following set of propositions appear not only individually indisputable, but leading to a logically inescapable conclusion:

1. The retention and development of lighting business is essential to the well-being of the gas industry.
2. The lighting business will not and cannot be retained or developed unless lighting service of a creditable sort is rendered with gas.
3. Creditable gas lighting service cannot be rendered to the public without the full and complete application of illuminating engineering principles and practices.

The timidity with which an innovation involving the modification of existing commercial practices is approached is more easily understood. Commercial practice is an uncharted sea. The engineer may predetermine the results of his practices to a high degree of accuracy. Having a light source giving 100 candlepower in a given direction, he knows that he may obtain an illumination of 1 foot-candle at a distance of 10 ft. in that direction. He does not need to make the actual experiment to vindicate the accuracy of his judgment, at least to any intelligent person. He has a firm basis of fundamental principles and definite laws expressing invariable relations, which make absolute certainty a possibility. The business man is not so favorably situated. There are no fundamental facts or laws of commerce. No commercial man can tell within limits of accuracy much larger than those obtainable in engineering calculations, the percentage of increase in sales which may be obtained by decreasing the price of an article by a given per cent., or by expending a given amount of money in advertising or in improvement of service. What he does know is that he will be blamed for any decrease of profits which *may follow* (*not necessarily result from*) any action which he may take. It is this incalculable hazard which makes business above all things conservative. "A bird in the hand is worth two in the bush," and prospective business is always very much of a bird in the bush.

But the application of sound principles to the sale of lighting involves neither great expenditure nor radical change of policy or practice. It requires only recognition of the following requirements and a reasonable effort to meet them:

First: Each customer should receive, within reasonable limits, the sort of service best suited to his needs, including proper selection and arrangement of lamps and reflectors with reference to hygienic, comfortable, adequate and economical illumination.

Second: The gas company should require that all salesmen be competent to advise the consumer correctly and honestly willing to do so, regarding the equipment best suited to his needs, and the method of installation; or, provide effective means for so supervising the activities of salesmen, through competent specialists, as to guard against at least the more flagrant violations of good lighting practice.

No company which honestly wishes to render reasonably good service can object to the general proposition that the first requirement *should* be met, nor is it likely that a more practical way of accomplishing this than is set forth in the second, will be found. Nothing is more certain than that the consumer who is left to his own devices, or abandoned to the mercies of a salesman who lacks special knowledge of lighting, will almost inevitably find himself burdened with an extravagant, poorly designed, harmful and generally disreputable system of illumination.

The effective way of abolishing this condition is, of course, to train the salesman. If he has the qualifications usually regarded as desirable, he will have no objection to selling the sort of equipment which will render the best services to the customer. If the salesmen are not inclined to show interest in the matter and the company feels doubts about its ability to get along without them it has the alternative of obtaining a special "lighting man" for the general supervision of the salesmen's practices in recommending equipment, and for special duty in handling particularly important installations. Several central stations and gas companies have tried the latter plan. In every case the results have entirely justified the innovation. Business heretofore regarded as hopeless has been retained and obtained. A general improvement in the tone and vigor of the lighting business has been noticeable.

But thus far there has been no company (at least among gas undertakings) willing to display the courage of its convictions and require that every salesman of lighting appliances shall know how lighting appliances should be used. The promptitude and extent to which this idea of the salesman's responsibility is accepted and put into practice among gas companies will largely determine the future position of gas lighting, and the domestic gas business.

* Prepared under the auspices of the
National Commercial Gas Association.

DISCUSSION.

W. J. CLARK: There is much fruitful thought contained in Mr. Pierce's able paper. I notice that he has touched upon a very important factor and one that has been discussed more or less in the gas convention papers and gas light journals, and that is the matter of costs, or getting what might be termed an inductive rate with which to attract business. In the electric field, rates are so flexible that you can practically make a rate for almost any applicant who asks for service.

The difficulties in meeting satisfactorily the situation in the gas business have been pretty well thrashed out, and the straight line meter rate still holds almost universally in the gas industry, and under the present abnormal conditions, it is a very grave question as to how long some of the gas companies can hold to these inflexible rates and live. Certainly the constantly increasing costs of labor and material indicate a fast diminishing margin of clearance. Before war conditions obtained, the matter of differential rates was discussed quite exhaustively and such factors as readiness-to-serve, customer and energy charge, were debated and although some few companies have introduced a rate for industrial gas carrying these cost factors the movement in this direction has not been general. Among the many troubles with which the gas industry has to meet is franchise requirements and restrictions laid upon the companies by local municipalities, and along with this, goes the very large question of adequate plant and distribution system which must be ample to meet the demands of proper service. This is particularly important when large industrial demands are to be met which carry through peak demand periods, and as I have said, although these questions have been

much discussed, it is far from a definite solution at this time, and is one on which the engineer and the commercial man must get together on.

In the lighting field, there is no question but that the electric industry has made great strides by reason of the fact that inductive rates could be made to the long hour user and the variety of ways by which this is done is infinite. It would seem that in view of the unquestioned economy and vast improvements in gas lighting which has been made in the last few years, we gas men with right economical methods should be able to hold a large place in the lighting field.

R. ff. PIERCE: Attention has been called to one thing which is to a large extent the principal stumbling block in the way of disseminating information regarding illuminating engineering, or rather the practice of lighting, among salesmen. The great question is to determine just how much a salesman should be expected to know about it. In practice we generally go to one extreme or another. A commercial manager of a large gas company attended a meeting in which a number of excellent papers on the subject of illuminating engineering and its application to central station practice, were read and discussed and he became quite enthusiastic about it and spoke to me afterwards, saying "I have a young man here who has only been with the Company a few weeks. I think he'd make an excellent lighting man, and I would like him to have all the knowledge he can obtain on the subject. If I send him to your factory, can't you give him some points?" I told him I would be glad to do so. "I am going to send him down and I want you to equip him so he can tackle any kind of a lighting subject that comes along and do it perfectly,—do it absolutely above criticism." "Well," I said, "How long do you think it is going to take?" "Oh, spend the whole afternoon on it, if you want to." That is one extreme—the man who thinks that all of the knowledge that a man needs on the subject should be absorbed in a few hours' conversation. Then there is the other extreme—the man who expects the salesman, who uses his knowledge of lighting at best in a rather casual way, to equip himself with all the technical knowledge that is required by a technical expert. Of course one extreme is as absurd as the other. All that a salesman

should be expected to know is, well, the sort of thing you expect a grocery's boy to know. If a woman goes into a grocery store and asks for something to make bread with, she doesn't expect to carry home a basket of tomatoes. A great many lighting salesmen sell equipment for lighting that is just as much out of place as a sofa pillow in a salad. A salesman should at least know enough about lighting so that he can guide the customer's selection of lighting along practical lines that will result in some benefit to the customer. He should know good lighting when he sees it, bad lighting when he sees it, and should be able to diagnose the case and tell why the good is good and the bad is bad, and know how to plan the good and how to eliminate the bad.

I am sorry to say that in many cases there seems to be a lack of entirely good faith in the attitude of some companies toward the education of their salesmen. I remember in particular I was asked one time to give a talk before employees of an industrial division handling lighting. They encountered a great many lighting problems and they wanted a talk on gas lighting of factories, so I said to the manager of the department before I went to the meeting. "I suppose what you want now is a plain, simple talk on how to plan lighting so as to give the greatest service and the greatest satisfaction to the customer." "Oh," he says, "No, we don't want that kind of stuff. We want a lot of peppery, general selling points, get-the-name-on-the-dotted-line stuff—that is what we want." That man didn't want to train his salesmen, didn't have the slightest idea of doing it. All he wanted was the order. After he got the order he was going to trust to the Lord that in some way or another, the customer would get some kind of satisfaction. That is what he actually meant as shown by his talk and his attitude. He practically said he wasn't willing to waste time teaching his men to plan the sort of service that would be useful and beneficial to the customer—he wasn't interested in that at all; what he wanted was some snappy peppery talking points that would enable him to close the order. I don't think that any company which really and honestly wishes its salesmen to learn enough about lighting so that they can intelligently direct the purchases of consumers will have any difficulty whatever in imparting or having imparted to their salesmen that sort of information. There is nothing complicated about it at all. I think

that the great trouble is that we are inclined to look upon illuminating engineering as too formidable. To the average man engineering means calculus, trigonometry and hieroglyphics of various kinds, because when he attends a convention at which technical papers are presented, he sees these various symbols that even the man who learned them in college forgets inside of two or three years, unless he happens to use them often. He imagines wherever he comes across the word 'engineering' it means complicate mathematics and long words of seventeen syllables—things difficult to understand. I think that is the most important thing to get out of his mind.

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TRANSACTIONS OF THE Illuminating Engineering Society

PART II -- PAPERS

VOL. XIII

APRIL 30, 1918

No. 3

REPORT ON CODE OF LIGHTING SCHOOL BUILDINGS.

The Code of Lighting School Buildings had its inception in the work of the Committee on School Lighting which was begun in 1915. Much of the material of the preliminary notes upon which the first draft of the code was based, is contained in the paper on "Safe-guarding the Eyesight of School Children" by M. Luckiesh, which was published in Vol. X of the TRANSACTIONS, 1915.

Drafts of the proposed code were submitted for criticism to architects, school superintendents, engineers and others identified with the problem of lighting school buildings. After extended discussion as to mooted questions of technical data and as to the scope of the material to be included in the code, a revised draft was prepared incorporating numerous suggestions and criticisms received to date. This draft was published August 30, 1917 as the first edition of the code, subject to final revision. Upwards of 900 copies of the first edition were distributed to a selected list, and further discussion and criticisms were invited. There were numerous responses to this appeal.

Before the final revision was made, a hearing on the code was held January 10, 1918, at a meeting devoted to this purpose by the New York Section of the Society.

In presenting the final draft, the Committees desire to point out that notwithstanding the great care used in its preparation, the code is admittedly imperfect and is not to be looked upon as an iron-clad pronouncement; the code is based on present ideas of good practice and it is hoped and expected that in the suc-

ceeding administrations, revisions will be made where necessary to bring the code up to date.

The present edition of the code contains very little technical data on daylight requirements. One reason for this omission is the lack of authoritative data on this subject; another reason is that the inclusion of even a general treatise on the day-lighting of school buildings would partake of the nature of a building code, requiring the presentation of plans and specifications which are considered beyond the scope of the present pamphlet. Many valuable suggestions and records relating not only to daylight but to artificial light requirements were not incorporated in the code for one reason or another, more particularly because of limitations of space.

The present code does not pretend to offer working plans and specifications for the lighting of buildings; nor does it pretend to offer articles in form for legislative enactment. Its purpose is mainly to serve as a guide in improving the lighting conditions in school buildings and as a basis for the enactment of rules and regulations and ordinances relating thereto.

The Committees wish to take this opportunity to acknowledge the kind co-operation of many architects, school superintendents, engineers and others—both members and non-members of the Society, too numerous to mention individually, who contributed valuable suggestions and criticisms.

Respectfully submitted,

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CODE OF LIGHTING SCHOOL BUILDINGS.

Article I. General Requirements.—When in use, all buildings should be provided, during those hours when daylight is inadequate, with artificial light according to the following Articles.

Buildings hereafter constructed should be so designed that the daylight in the work space is reasonably uniform and the darkest part of any work space is adequately illuminated under normal exterior daylight conditions.¹

Article II. Intensity of Artificial Illumination.—The desirable illumination to be provided and the minimum to be maintained are given in the following table:²

DESIRABLE AND MINIMUM ILLUMINATION.

	Artificial lighting Foot-candles (Lumens per square foot)* At the work	
	Minimum	Ordinary practice†
Storage spaces	0.25	0.5- 1.0
Stairways, corridors	0.5	1.0- 2.5
Gymnasiums	1.0	2.0- 5.0
Rough shop work	1.25	2.0- 4.0
Auditoriums, assembly rooms	1.5	2.5- 4.0
Class rooms, study rooms, libraries, laboratories, blackboards	3.0	3.5- 6.0
Fine shop work	3.5	4.0- 8.0
Sewing, drafting rooms	5.0	6.0-12.0

Article III. Shading of Lamps.—Lamps should be suitably shaded to minimize glare. Glare, either from lamps or from unduly bright reflecting surfaces, produces eye-strain.

* It should be borne in mind that intensity of illumination is only one of the factors on which good seeing depends.

† Under the column headed "Ordinary practice," the upper portion of the range of intensities is preferable to the lower; where economy does not prohibit, even higher intensities than those cited are often desirable.

¹ Daylight illumination values should be at least twice the values given in the Table Article II, for artificial lighting.

² The illumination intensity should be measured on the important plane which may be the desk-top, blackboard, etc.

The method of computing the flux of light (lumens) required to do any desired illumination is described under the heading "Design of Lighting Installation" on page 15.

For more specific information regarding the lighting of shops, see "*Code of Lighting Factories, Mills and Other Work Places*", issued by the Illuminating Engineering Society

Article IV. Distribution of Light on the Work.—Lamps should be so arranged as to secure a good distribution of light on the work, avoiding objectionable shadows and sharp contrasts of intensities.

Article V. Color and Finish of Interior.—Walls should have a moderate reflection factor; the preferred colors are light gray, light buff, dark cream and light olive green. Ceilings and friezes should have a high reflection factor; the preferred colors are white and light cream. Walls, desk-tops and other woodwork should have a dull finish.

Article VI. Switching and Controlling Apparatus.—Basements, stairways, store rooms, and other parts of the building where required, should have switches or controlling apparatus at point of entrance.

Article VII. Emergency Lighting.—Emergency lighting should be provided at main stairways and exits to insure reliable operation when, through accident or other cause, the regular lighting is extinguished.

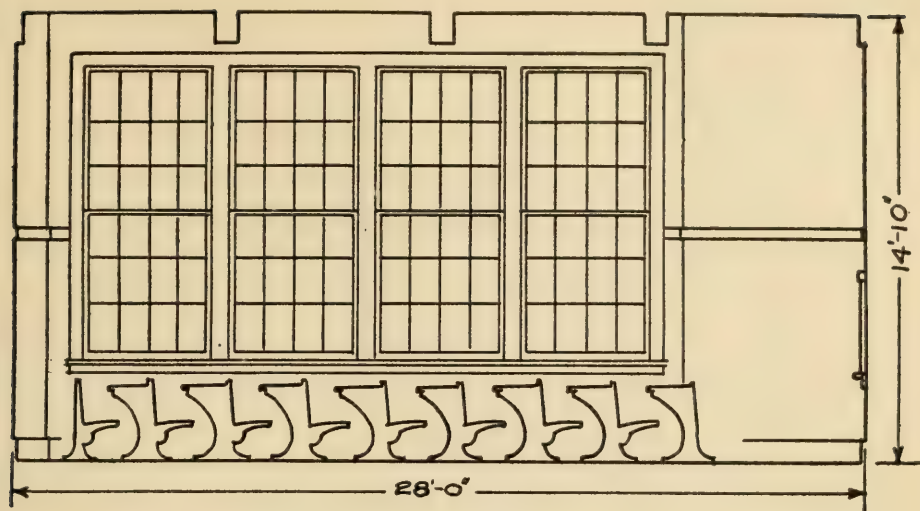
Article VIII. Inspection and Maintenance.—All parts of the lighting system should be properly maintained to prevent deterioration due to dirt accumulation, burned-out lamps and other causes. To insure proper maintenance, frequent inspection should be made at regular intervals.

NOTES—Data and Recommendations.

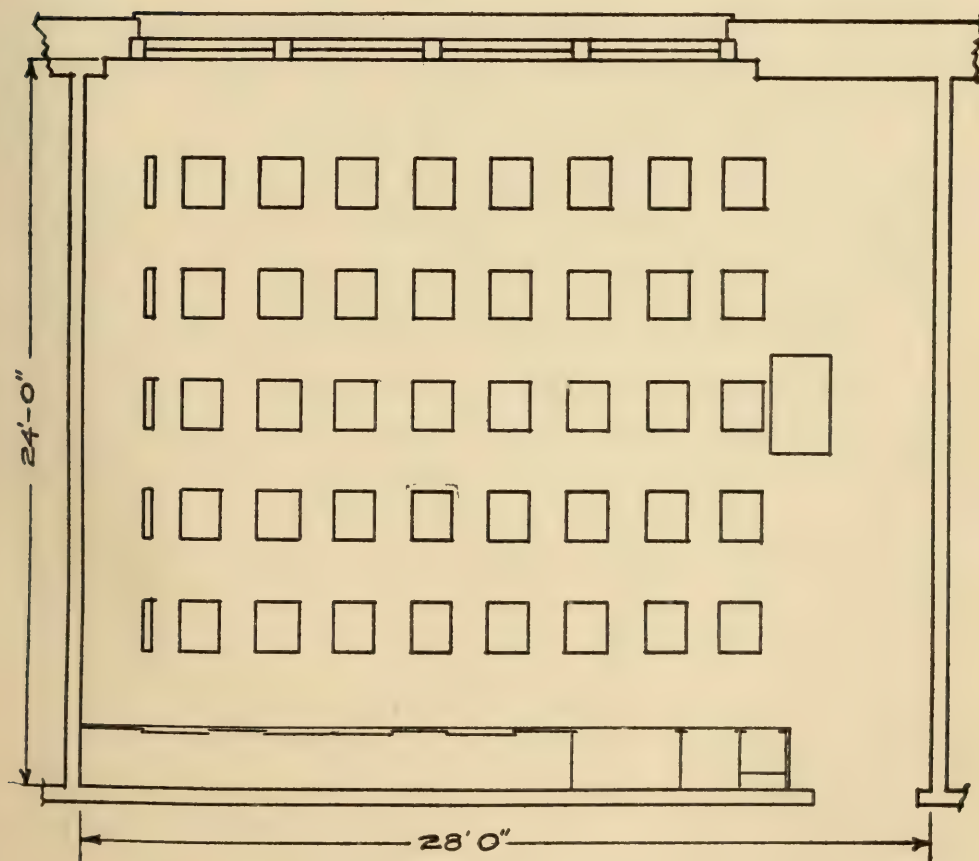
DAYLIGHT.

Intensity of Daylight.—In general, the minimum intensities of daylight illumination should be considerably greater than those provided in artificial lighting, owing to the adaptation of the eye to a much higher level of illumination (brightness) in the daytime.

Direction of Light.—One of the fundamental rules for proper lighting of desks is to have the preponderance of light come from



ELEVATION.



PLAN.

Fig. 1.—Unilateral daylighting. Scaled drawing of a typical modern class room.

the left side. For this reason many school authorities advocate *unilateral* lighting, that is, lighting by windows located on one side of the room only, especially for class rooms (see Fig. 1). This method of lighting is recommended where the rooms do not exceed about 24 ft. (7.9 m.) in width, with windows about 12 ft. (3.9 m.) high. If the rooms are much wider than this, *bilateral* lighting, that is, lighting by windows located on two sides of the room, may be required in order to provide sufficient illumination in every part of the room and at the same time to prevent too great a diversity of contrast in the intensity of light on the work spaces.

To secure the highest lighting value it is recommended that the room be so designed that no working location is more distant from a window than one and one-half times the height of the top of the window from the floor.

Windows at the left and rear where practicable are preferable to those on the left and right sides of the room, because of cross shadows created by the latter arrangement. Lighting by overhead sources of natural illumination although sometimes used for assembly rooms, auditoriums and libraries, with relatively high ceilings, has ordinarily little application in class rooms and has found little favor in practice.

The sky as seen through a window is a source of glare. For this reason the seating arrangements should always be such that the occupants (pupils) of the room do not face the windows.

Window Openings.—Tests of daylight in well lighted school buildings indicate that, in general, the glass area does not fall below 20 per cent. of the floor area.

As the upper part of the window is more effective in lighting the interior than the lower part, it is recommended that the windows extend as close to the ceiling as practicable.

Lighting Value of a Window.—The lighting value of a window at any given location in the room, will depend upon the brightness of the sky, the amount of sky visible through the window at the given location in the room, and indirectly upon the reflection factor of the surroundings and the dimensions of the room.

Observations in well lighted school rooms having a comparatively unobstructed horizon, show that under normal conditions

of daylight, satisfactory illumination is usually obtained when the visible sky subtends a minimum vertical angle of 5° at any work point of the room.

In cases in which the horizon is obstructed, as by adjacent high buildings or by high trees, provision should be made for a larger window area than would otherwise be required; also if need be, for redirecting the light into the room by means of prismatic glass in the upper sashes of the windows, or by prisms canopies outside of the windows.

Window Shades.—Although direct sunlight is desirable in interiors from a hygienic standpoint, it is often necessary to exclude or diffuse it by means of shades. These shades should perform several functions, namely, the diffusion of direct sunlight, the control of illumination to secure reasonable uniformity, the elimination of glare from the visible sky and the elimination of glare from the blackboards wherever possible. These requirements make it desirable to equip each window, especially in class rooms, with two shades operated by double rollers placed near the level of the meeting rail. The window shades may thus be raised or lowered from the middle, which provides the maximum elasticity for shading and diffusing the light. The shades should be preferably of yellow-colored material that is sufficiently translucent to transmit a considerable percentage of the light while at the same time diffusing it.

A more complete control of the light may be obtained by the use of two independent sets of shades at each window. Where two sets of shades are used, one should be preferably a very dark green of heavy material that will exclude the light entirely, and the other preferably a yellow-colored material as above described.

Different views of a window equipped with a single set of adjustable shades as used in the public schools of New York City are shown in Fig. 2. It will be noted that this method of installation permits of lowering the window from the top or raising it from the bottom without interference with the shades.

Light Courts.—Reflection of light from the walls of courts is very helpful in increasing interior illumination. Hence the walls of courts should have high reflection factors. Dark colors should be avoided.

Maintenance.—Windows and overhead sources of natural light (so-called skylights) should be washed at frequent intervals and surfaces such as ceilings and walls should be cleaned and refinished sufficiently often to insure their efficiency as reflecting surfaces. It should be borne in mind that the maintenance of adequate daylight indoors is also dependent upon various external factors, such as the future erection of buildings and the growth of trees or vines.

ARTIFICIAL LIGHT.

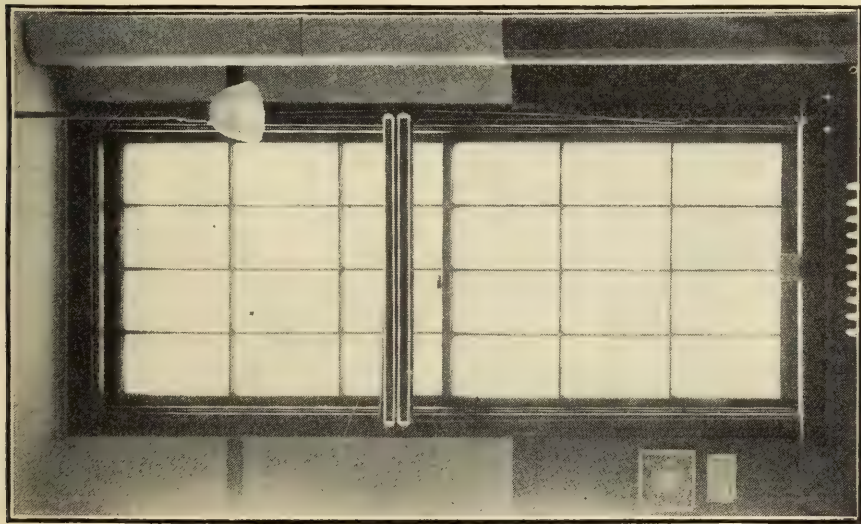
Systems of Lighting.—It is customary to divide the systems of artificial lighting into three classes, namely, *direct*, *semi-indirect*, and *indirect*. This division is arbitrary and the boundary lines are quite indefinite.

A direct lighting system is known as one in which most of the light reaches the work plane directly from the lighting unit including the accessory which may be an opaque or glass reflector or a totally enclosing transparent or translucent envelope. Direct lighting systems may be further classified as *localized* and *general* or distributing. In the former the units are so placed as to light local work spaces, and in the latter they are well distributed so as to light the whole area more or less uniformly.

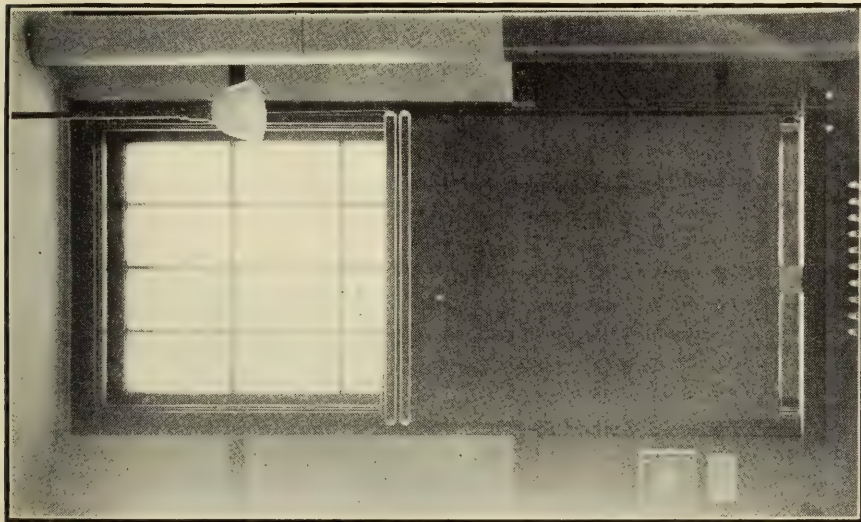
A semi-indirect system is known as one in which a portion of the light reaches the work plane directly from the unit and a relatively large portion reaches the work plane indirectly, by reflection from the ceiling and walls. The accessory is usually an inverted diffusing bowl or glass reflector. When this glass has a high transmission factor the lighting effect approaches that of ordinary direct lighting, and when of low transmission, the effect approaches that of indirect lighting.

An indirect system is known as one in which all or practically all the light reaches the work plane indirectly after reflection from the ceiling and walls. The accessory is usually an opaque or slightly translucent inverted bowl or shade containing a reflecting medium.

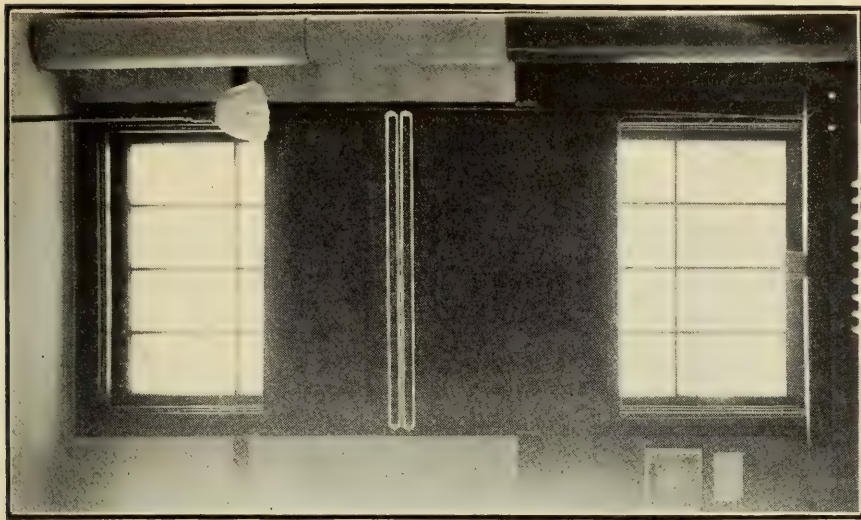
All three of these systems of lighting (illustrated in Figs. 3, 4, and 5) are in successful use in schools. There has been a growing preference for semi-indirect and indirect lighting, especially since the introduction of modern lamps of great brilliancy. Local lighting by lamps placed close to the work is unsatisfactory ex-



A



B



C

Fig. 2.—Double-roller window shades as used in a public school building.



Fig. 3.—Good direct lighting.
In general, semi-indirect or indirect lighting is better for school rooms.



Fig. 4.—Good indirect lighting.

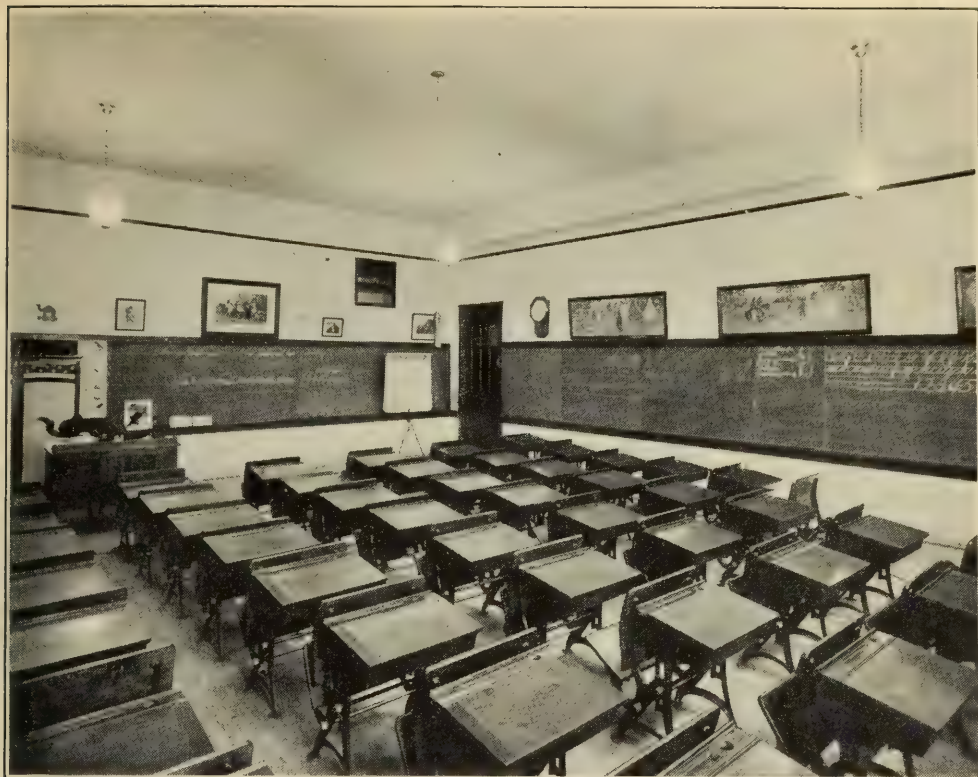


Fig. 5 —Good semi-indirect lighting.



Fig. 6.—Bad lighting. The lighting units are hung too low and the light sources are not adequately shaded. Note the glossy varnished surfaces on benches and woodwork.

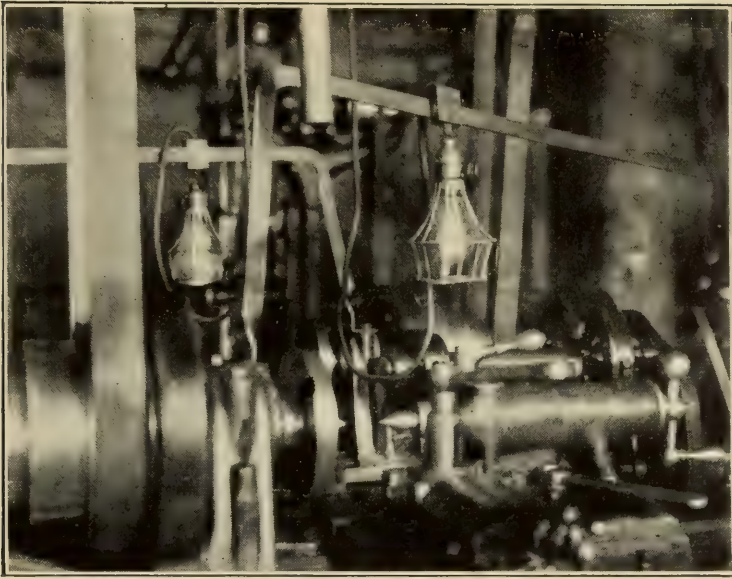


Fig. 7.—Bad lighting. The local lamps, if used at all, should be provided with reflecting shades to protect the eyes from glare and at the same time to direct the light to the work. General illumination by overhead units is preferable.

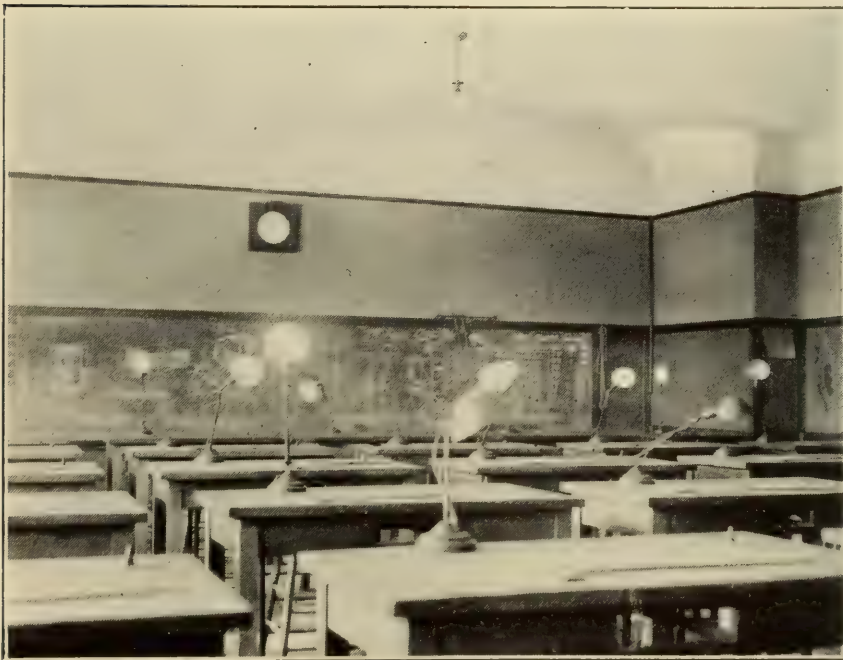


Fig. 8.—Bad lighting. The use of local lighting by adjustable table lamps usually results in glare from lamps on neighboring tables; also in annoying shadows. The difficulties may be overcome by the use of a system of general illumination.

cept for special cases such as the lighting of blackboards, maps, charts, etc. Examples of bad lighting are shown in Figs. 6, 7, and 8.

Shading of Lamps.—Except in very rare instances bare light sources should not be exposed to view. They should always be adequately shaded or completely hidden. Even when shaded by translucent media, such as dense glassware, the lighting units should be placed well out of the ordinary range of vision; in other words it is recommended that lighting units be of low brightness,³ even if they are located high in the field of view.

The maximum brightness contrast of juxtaposed surfaces in the normal visual field should be preferably not greater than 20 to 1; that is to say, the darkest part of the work space observed should have a brightness preferably not less than one-twentieth of that of the brightest part.

Glossy Surfaces and Eye-Strain.—Glossy surfaces of paper, woodwork, desk-tops, walls and blackboards are likely to cause eye-strain because of specular or mirror-like reflection of images of light sources, especially when artificial light is used. Matte or dull finished surfaces are recommended. It is to be noted that a high reflection factor does not necessarily imply a polished or glazed surface.

To minimize eye-strain it is recommended that unglazed paper and large plain type be used in school books.

³ Preferably not to exceed 250 millilamberts. A millilambert is equal to the brightness of a perfectly reflecting and diffusing surface illuminated to an intensity of 0.929 foot-candle, (0.929 lumen per square foot). It is also equal to 0.002 candle per square inch.

The following table shows the order of magnitude of the brightness of some light sources in common use:

	Approximate brightness	
	Millilamberts	Candles per sq. in.
Indirect lighting: ceiling, directly above the lighting unit	5. to 75.	0.01 to 0.15
Semi-indirect lighting: heavy density glassware	35. to 100.	0.07 to 0.2
“ “ “ light density glassware	200. to 1,000.	0.4 to 2.0
Direct lighting: 10 in. (25 cm.) opal glass ball containing 100-watt vacuum tungsten lamp at center	250. to 500.	0.5 to 1.0
“ “ vacuum tungsten lamp, (frosted) in open bottom reflector	2,000. to 3,000.	4. to 6.
Vacuum tungsten lamp, filament exposed to view	500,000.	1,000.
Gas-filled tungsten lamp, filament exposed to view	2,000,000.	4,000.
Gas-mantle, bare	15,000.	30.
“ “ concealed in 6 in. (15 cm.) opal glass globe	1,000.	2.
Mercury arc tube (glass)	8,000.	16.
Daylight: clear blue sky	1,000.	2.

Children should be taught to hold their books properly, to assume a correct position relative to the light source, and to safeguard their vision.

Color of Light.—It has been found in practice that the admixture of daylight and artificial light is not satisfactory unless the latter is derived from lamps designed with special reference to producing daylight color values. Hence in waning daylight it is desirable to shut out the daylight and to use artificial light exclusively unless the lamps are of the type mentioned.

Design of Lighting Installation.—The illumination intensity on the horizontal work plane should be as uniform as possible. The variation should not be greater than 4 to 1.⁴

APPROXIMATE COEFFICIENTS OF UTILIZATION—MODERN LIGHTING EQUIPMENT.

Small Rooms (Offices, Corridors, etc.).

	Light color walls Light color ceiling	Medium color walls Light color ceiling
Direct lighting; dense glass (open bottom reflectors)	0.40	0.35
Semi-indirect lighting; dense glass.....	0.25	0.22
Indirect lighting	0.23	0.20

Medium Sized Rooms (Class Rooms, Laboratories, etc.).

Direct lighting; dense glass (open bottom reflectors)	0.50	0.45
Semi-indirect lighting; dense glass.....	0.35	0.30
Indirect lighting	0.30	0.25

Large Rooms (Auditoriums, etc.).

Direct lighting; dense glass (open bottom reflectors)	0.62	0.60
Semi-indirect lighting; dense glass.....	0.43	0.40
Indirect lighting	0.40	0.38

The chief factors which must be considered in arriving at the size and number of lamps to be used in a given room are (1) the floor area; (2) the total luminous flux⁵ emitted per lamp, and

⁴ This ratio refers to the light received by the object illuminated and should not be confused with the ratio of 20 to 1 for brightness contrast previously given on page 10, which refers to the light radiated by the object. For example, a blackboard and a white sheet of paper on it may receive the same amount of light, but the latter will reflect much more light than the former, thus causing a marked brightness contrast between the two surfaces.

⁵ The flux is measured in lumens. A lumen is the unit of light flux and is the quantity of light required to illuminate 1 square foot of area to an average intensity of 1 foot-candle.

(3) *coefficient of utilization* of the particular system considered. The first should be measured in square feet. The second may be obtained from a data book supplied by the manufacturers of lamps. The third involves many factors such as the relative dimensions of the room, the reflection factor of the surroundings, the number of lighting units and their mounting height, and the system of lighting. By *coefficient of utilization* is meant the proportion of the total light flux emitted by the lamps which is effective on the work plane. In the accompanying table approximate coefficients of utilization for modern lighting equipment are given. The work plane in this case is a horizontal plane 30 in. (76 cm.) above the floor. These values refer to the initial installation without any allowance for depreciation.

For determining approximately the size and number of lamps to be used in a given room by means of the coefficients of utilization given in the preceding table, it is necessary to know the luminous output in lumens per watt for the electric lamps considered or in lumens per cubic foot of gas consumed per hour if gas lamps are considered. At the present time (1917) the light output of tungsten filament electric incandescent lamps, based on average service conditions of regularly maintained installations, ranges from 8 lumens per watt for the smaller vacuum tungsten lamps to 14 lumens per watt for the larger gas-filled tungsten lamps employed in school lighting. For incandescent gas systems similar service values range from 150 to 250 lumens per cubic foot of artificial gas consumed per hour. The computation for the total lumens required to give a certain illumination intensity in foot-candles is as follows:

N = number of lamps.

L = lumens output per lamp.

E = coefficient of utilization.

A = area of floor or horizontal work plane in square feet.

I = illumination intensity in foot-candles.

$$\frac{N \times L \times E}{A} = I$$

that is, the number of lamps multiplied by the output per lamp in lumens, multiplied by the coefficient of utilization, divided by the area of the horizontal work plane in square feet, gives the illumination intensity in foot-candles.

If the size of the lamps is to be ascertained the computation is made thus:

$$L = \frac{I \times A}{N \times E}$$

To illustrate by an example, assume a room, whose floor (also work plane) is 30 ft. by 18 ft. (9.1 by 5.5 m.), to be lighted by a semi-indirect system from six fixtures containing one lamp each. It will also be assumed that the ceiling is highly reflecting, the walls moderately reflecting, and the illumination intensity desired is 5 foot-candles. The luminous output required of each of the six lamps will be found by substituting the assumed values in the equation, thus:

$$L = \frac{5 \times 30 \times 18}{6 \times 0.30} = 1,500 \text{ lumens}$$

Allowing a depreciation factor of 20 per cent. as representing a well maintained installation, the lumens actually required would be $\frac{1,500}{0.8} = 1,875$ lumens. If gas-filled tungsten lamps are considered, whose average output under service conditions is 12 lumens per watt, it is seen that a 150-watt lamp in each fixture will give the desired results.

If gas mantle lamps are considered, whose average output in lumens under service conditions is 250 lumens per cubic foot of gas consumed per hour, it is seen that a lamp consuming 5 cubic feet of artificial gas per hour will be satisfactory in each fixture.

The above example is intended solely to illustrate the method of computation. Estimates of the illumination intensity obtained from an actual installation may also be made by a similar computation.

Suitable switching and controlling arrangements should be made to permit of lighting one or more lamps independently as conditions may require.

The teacher's desk may be illuminated by one of the overhead lighting units, or if necessary, by a desk lamp.

With the usual lighting equipments the distance between the units should not exceed one and one-half times the height of the apparent source of illumination above the working level.

Blackboards.—Blackboards should be of minimum size practicable and should not be placed between windows. Their posi-

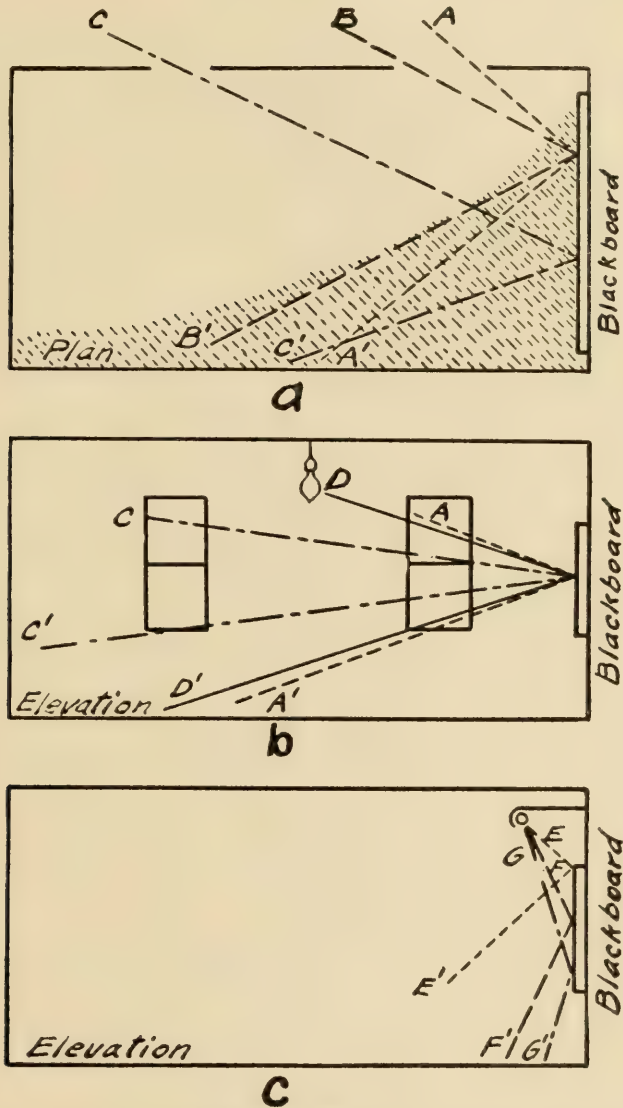


Fig. 9.—Diagrammatic illustration of glare from blackboards.

- (a) Showing that occupants of seats in shaded area are subjected to daylight glare from blackboards.
- (b) Showing angles at which glare is experienced from daylight and from artificial light.
- (c) Arrangement of local artificial lighting to minimize glare.

tion should be carefully determined so as to eliminate the glare due to specular reflection of images of either artificial or natural light sources directly into the eyes of occupants of the room. The surface of blackboards should be as dull as possible and this dullness should be maintained.

Glare, due to specular reflection from blackboards, may be reduced or eliminated by lighting them by means of properly placed and well shaded local artificial light sources.

In Fig. 9 are shown some simple graphical considerations of blackboard lighting. In (a) is shown a plan view of a room with windows on one side. Rays of light are indicated by A, B and C in a horizontal projection. These are supposed to come from bright sky. By the application of the simple optical law of reflection—the angle of incidence is equal to the angle of reflection—it is seen that pupils seated in the shaded area will experience glare from the blackboards on the front wall. In (b) is shown the vertical projection of the foregoing condition. It will be apparent from this graphical illustration that by tilting the blackboard away from the wall at the top edge, the pupils in the back part of the room will be freed from the present glaring condition. Whether or not this tilting will remedy bad conditions may be readily determined in a given case. In (b) the effect of specular reflection of the image of an artificial light source is shown by D. In (c) is shown a proper method of lighting blackboards by

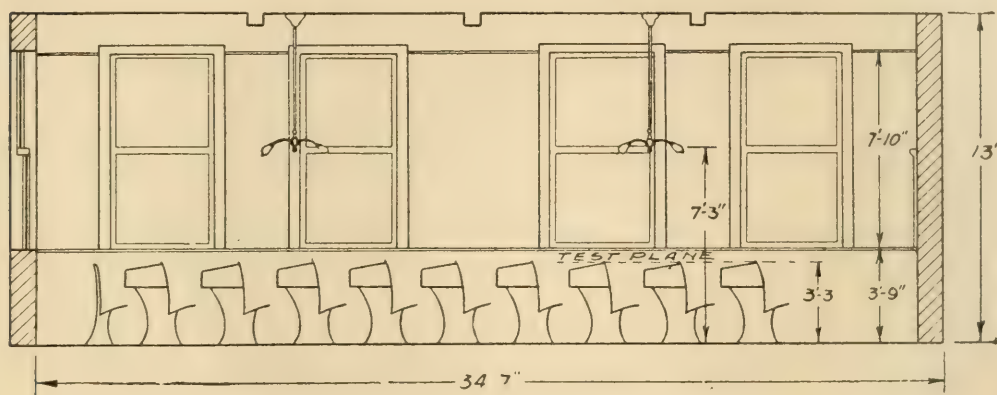



Fig. 10 (a).—Old artificial lighting equipment.

means of artificial lighting units. This will often remedy bad daylight conditions whether due to an insufficient illumination intensity of daylight or due to reflected images of a patch of sky.

In order to avoid excessive brightness contrast which is trying to the eyes, blackboards should not be placed on a white or highly reflecting wall.

Rehabilitating the Lighting of Old Buildings.—This will be illustrated by an actual case where the artificial lighting of a class

room was made satisfactory at a small expense. In Fig. 10 (a) is shown an elevation of a section of the class room showing the old fixtures. In Fig. 10 (c) the circles containing crosses () indicate the positions of the two old fixtures in this room. The chief objections to this old system were as follows:

(1) The lighting units were hung too low, so that eye-fatigue resulted from the bright sources in the visual field.

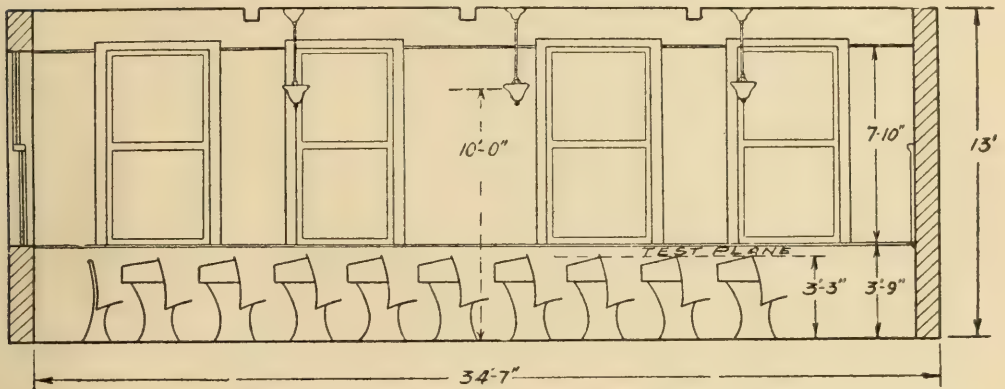


Fig. 10 (b).—New artificial lighting equipment.

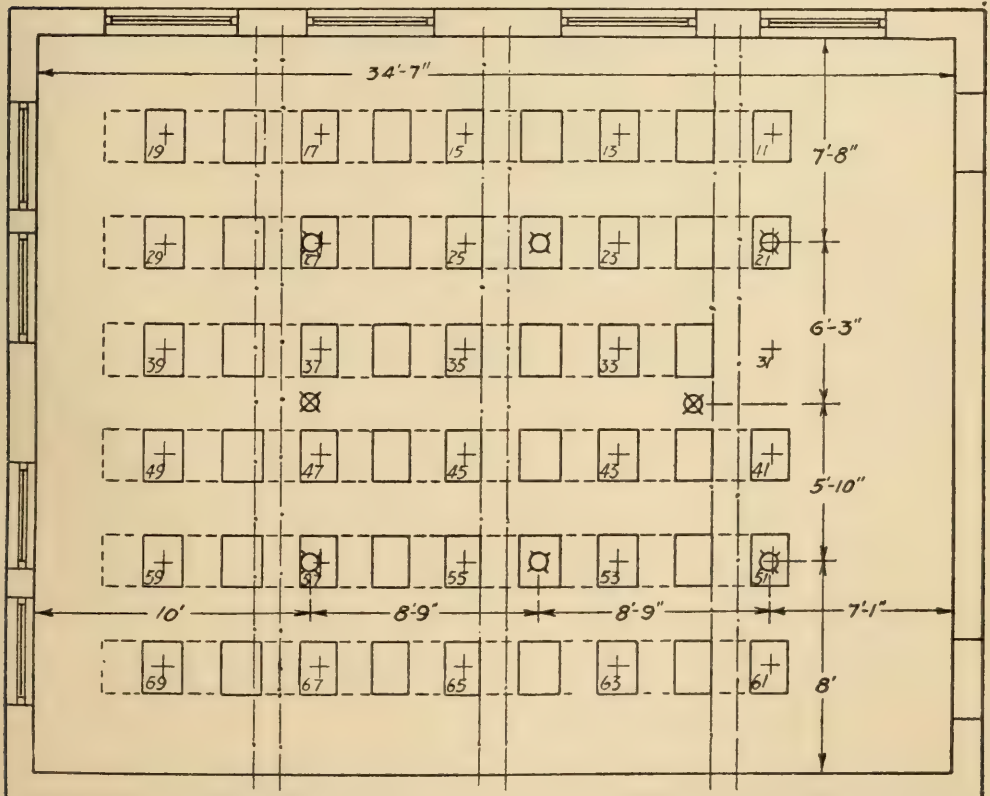


Fig. 10 (c).—Old (⊗) and new (⊘) outlets for artificial lighting equipment in a classroom.

(2) The light sources were not shielded from the pupils' eyes.

(3) Two fixtures are insufficient to provide satisfactory illumination over the entire work plane in a room of the dimensions shown. This unsatisfactory condition was remedied by means of six fixtures placed as indicated by the circles (⊗) in Fig. 10 (c).

These fixtures, shown in elevation in Fig. 10 (b), consisted of inverted diffusing glass shades containing one lamp each. The dimensions of the room are shown in the illustration.

Maintenance.—A systematic maintenance should be provided in order to insure against depreciation in the illumination intensity due to burned-out lamps, broken gas mantles, discoloration, etc., and to accumulations of dirt upon the lamps, and upon the surfaces of the reflecting and transmitting media. It is found in practice that carelessness in this respect may easily reduce the effective illumination by 50 per cent., especially in indirect and semi-indirect lighting.

THE GENERAL LEVEL OF ILLUMINATION INTENSITIES IN LARGE DEPARTMENT STORES OF NEW YORK CITY.*

BY W. F. LITTLE AND J. F. DICK.

A query received by the Electrical Testing Laboratories from an out-of-town client concerning practice in illumination intensities in New York's department stores has led to a rather casual survey. This survey has developed some information which seems worth including in a brief paper in the *Illuminating Engineering Society Transactions*. In the course of this work illumination observations were made at counter height with the aid of a "foot-candle meter"¹ on various floors and in various departments of eight of the large stores in New York. As an exhaustive illumination test was not intended, no wattage measurements were made and no individual lamps were measured for conformance to rating. In all cases the wattage values per fixture and per lamp were taken as given by the store management. No correction was made for the age or deterioration of the lamps, or condition of glassware. Some of the measurements were made in the winter months and others in the summer months and most of them during business hours. In considering the results obtained it may be well to bear in mind that in the winter season more attention is probably paid to the lighting conditions in these stores, and that somewhat different results may obtain. The stores investigated are as follows:

B. Altman & Company.....	34th St. and Fifth Ave.
Arnold Constable & Company.....	40th St. and Fifth Ave.
Best & Company.....	35th St. and Fifth Ave.
Gimbel Brothers.....	33rd St. and Sixth Ave.
Lord & Taylor.....	38th St. and Fifth Ave.
James McCreery & Company.....	W. 34th St.
Rogers Peet Company.....	41st St. and Fifth Ave.
Stern Brothers.....	42nd St. and Sixth Ave.

* A paper prepared for the 1916-17 Correspondence Convention of the Illuminating Engineering Society, and circulated among members of the Society and others who were thought to be interested in the paper. This paper was also presented by the authors before the New York Section September 13, 1917.

¹ *Electrical World*, Sept. 6, 1916.

The obligation of the authors to the management of each of these stores is expressed. Their courteous co-operation made this survey practicable.

The average illumination intensity in lumens per square foot or foot-candles is shown in Table I, the stores being arranged in an order different from the alphabetical order used above. In all cases typical values for particular floors are shown.

Considering the foregoing, it is fair to say that at the time of this investigation the general level of illumination intensity in these larger New York department stores was of the order of $4\frac{1}{2}$ foot-candles, ranging for the several stores from a minimum of $1\frac{1}{2}$ to a maximum of $7\frac{1}{2}$ foot-candles.

A general all-around figure for wattage seems to be in the neighborhood of 1 watt per square foot, and only where color modification is desired is this figure greatly exceeded.

In cases where color modification is desired, some stores use 2 to $2\frac{1}{2}$ watts per square foot to secure the desired intensity. In some of these cases, however, the fixtures are very dense and the lamps themselves of comparatively low efficiency, and in others high efficiency lamps are used in bluish white diffusing bowls. In still other cases, blue bulb gas-filled tungsten lamps are used in bowls or enclosing globes which do not of themselves modify the color of the light. Gas-filled tungsten lamps are largely used, except where a warmer color of light is desired.

There is a considerable tendency toward the use of a single fixture in the center of each bay and units of large area with high candlepower lamps, with a disregard for total watts consumed. The totally enclosing or covered unit is used in the majority of cases, and where not used a number of complaints were noted in regard to the necessity of frequent cleaning. Many of the large bowls, more or less hemispherical in shape, are equipped with either opaque or translucent covers designed to act as reflectors.

With very few exceptions, an entire floor is lighted by general illumination without any assistance from smaller local units. Table II shows the types of fixtures and the extent to which they are used, also their re-directing characteristics. In fact, only in

TABLE I.—DATA OBTAINED FROM LIGHTING SURVEY.

Store	Floor	Fixtures			Lamps		Watts per sq. ft. of floor area (approx.)	Average lumens per sq. ft. (horizontal)	Per cent. flux delivered to working plane (approx.)
		Type	Diam.	Character of glass	Type	Size, watts			
A	Main and 2d Above 2d	Glass bowls—tops covered	22 in. (56 cm.)	Dense, bluish white	Mazda C	500	7.5	7.5	
		Totally indirect—metal reflector			Mazda C				
B	Main 2d, 3d and 4th 7th and 8th	Glass bowls—tops covered	22 in. (56 cm.)	Dense, bluish white	Mazda C	500	4 to 5	4 to 5	
		Totally enclosing balls		Clear, prismatic upper, ground lower	Mazda B	100	2	2	
C	Main 2d, 3d and 4th 5th 6th	Glass bowls—tops covered	22 in. (56 cm.)	Dense, bluish white	Mazda C	750	1.25	3.5	20
		Glass balls—enclosing	18 in. (46 cm.)	Dense, bluish white	Mazda C	750	1.2	3.5 to 4.0	20 to 25
		Totally indirect—metal reflector	22 in. (56 cm.)	Dense, bluish white	Mazda B	400	1.7	2.3	20
		Glass balls—enclosing	18 in. (46 cm.)	Dense, bluish white	Mazda C	750	0.9	4.5	25
D	Basement and main floor	Glass hemispheres—open. Also numerous small brackets	16 in. (41 cm.)	Dense, bluish white & Translucent white	Mazda C	200	5.0	5.0	
					Mazda B				
E	Main, 2d and 3d	Glass acorns—totally enclosing		Medium, reddish white	Mazda C-2	100 & 150	1.5		
F	Main 2d 3d	Glass bowls—tops open		Dense, white impregnated with blue	Mazda B	900*	2.4	3.5	15
		Ditto		Ditto	Mazda B	600*	1.6	5.2	30
		Ditto		Dense white	Mazda B	240*	0.6	3.2	40
G	Main 2d 3d 5th	Glass balls—totally enclosing	14 in. (36 cm.)	Crystal, roughed inside	Mazda B	150	1.2	4.5	35
		Ditto	10 in. (25 cm.)	Ditto	Mazda B	100	0.8	3.8	45
		Ditto	10 in. (25 cm.)	Ditto	Mazda C-B	100 & 150	1.0	4.5	40
H	Basement	Glass reflector—direct lighting		Prismatic	Mazda C-B	100	0.8	3.5	40
		Ditto		Opal, medium	Mazda B	60	0.5	1.5	30
		Glass bowls—tops open	25 in. (64 cm.)	Medium, dense white	Mazda C	300 & 400	1.0	3.7	25
		Ditto	25 in. (64 cm.)	Ditto	Mazda C	400	1.1	5.0	25
	2d 3d 4th	Ditto	21 in. (53 cm.)	Ditto	Mazda C	300	0.8	3.4	25
		Ditto	21 in. (53 cm.)	Ditto	Mazda C	300	0.8	6.0	40

* Six lamps per fixture.

TABLE II.—TYPES OF FIXTURES IN STORES IN WHICH
SURVEY WAS MADE.

Type of fixture	Approximate ratio upward to downward flux	Number of floors so equipped
Dense bowls, tops covered.....	$\frac{30}{70}$	7
Dense bowls, tops open	$\frac{80}{20}$	9
Prismatic and ground balls.....	$\frac{15}{85}$	2
Enclosing globes	$\frac{45}{55}$	7
Indirect.....	$\frac{100}{0}$	3
Direct lighting	$\frac{10}{90}$	2
CRI balls	$\frac{45}{55}$	3
Total floors		33

cases such as shoe departments and millinery departments, etc., where the directional as well as the quantitative element is important, is local illumination found. In spite of the use of a uniform general lighting system, the ratio of maximum to minimum intensity in most cases is found to be very low; and only where large fixtures with low mounting heights are found is the variation in intensity excessive.

The distribution of light from the several lighting units varies considerably among the different stores. Installation practice differs also. In consequence, the uniformity of light distribution varies. Typical ratios of maximum to minimum as found in the several stores are shown in Table III.

From the conventional illuminating engineering point of view, some of the differences in illumination intensities among various floors of some of these stores seem unreasonable. The authors, however, have not studied the department store lighting problem as such, and are unable to say whether some of the more notable differences exist by design or otherwise. It would be interesting to learn, for example, whether or not in department store lighting it is regarded as desirable to illuminate white goods departments to a much higher intensity than furniture and rug departments.

TABLE III.—TYPICAL LIGHT INTENSITY VALUES FOUND ON THE SEVERAL FLOORS.

Store	Floor	Lumens per square foot (horizontal)			
		Max.	Min.	Mean	<u>Max.</u> <u>Min.</u>
A	Main	19	3	7.5	6.3
B	Main	12	3.5	4.5	3.4
	Second	11	3.0	4.5	3.7
	Third	19	4	5	4.7
	Fourth	10	3	4	3.3
	Seventh	3	1.5	2	2.0
	Eighth	3	1.5	2	2.0
C	Main	6	3	3.5	2.0
	Second	7	2.25	3.5	3.1
	Third	7.5	1.5	3.5	5.0
	Fourth	11	1.5	4.0	7.3
	Fifth	3	1.25	2.25	2.4
	Sixth	10	2.25	4.5	4.4
D	Basement	6	3.5	5.0	1.7
	Main	6	4	5	1.5
E	Main	2.5	1.2	2.0	2.1
	Second	2.5	0.9	1.5	2.8
	Third	2.0	0.6	1.4	3.3
F	Main	5	3.5	4	1.4
	Second	7	4	5	1.7
	Third	4.75	2	2.75	2.4
G	Main	5	4.25	4.5	1.2
	Second	4	3	3.75	1.3
	Third	4.75	3.75	4.5	1.3
	Fifth	4.5	3.25	3.5	1.4
	Basement	3.5	1	1.5	3.5
H	Main	6	2.5	3.75	2.4
	Second	9	2.5	5.0	3.6
	Third	6	2.4	3.5	2.5
	Fourth	10	2.8	6	3.6

In several stores, departments such as the furniture and rug prefer a low intensity, and their reason is that neither furniture nor rugs show to their best advantage under a high illumination. This opinion seems quite general among the department store managements. The general practice for basements, consisting of a number of departments, seems to be the use of direct lighting fixtures.

After all, the principal problem in this class of commercial lighting is so to design the lighting as to promote sales. But little information is available on the relation between lighting and sales.

The authors desire to make it clear that they do not wish to imply that intensity of illumination is the sole index to the quality of the lighting in department stores. As in all other illuminating engineering work, color, diffusion and direction of the light are important, as well as the appearance of the lighting installation. As this paper makes no pretense to report a comprehensive survey, no hesitancy is experienced in limiting its data to illumination intensities alone.

DISCUSSION.

F. H. MURPHY: I would like to inquire if the tests were made by placing the instrument on the counter in various locations or whether some certain section of the store was blocked off and an arbitrary level (approximately counter height) used for all the readings.

Also, I would like to ask the authors how the ratio of upward to downward flux was determined in the case of these installations.

Since receiving this paper I have not had the opportunity to make a similar test upon our own department stores. I have, however, a record of a test made some two or three years ago upon one of our better class of stores, where indirect lighting fixtures were installed at the time, which gave an average intensity of about 6.1 lumens per sq. ft. with a ratio of maximum over minimum of 2.7 and a wattage of 1.26 per sq. ft. 100-watt clear glass high efficiency vacuum lamps were used, six in each fixture, a single fixture being located in the center of each bay which is approximately 22 ft. (6.1 m.) square. At the time the test was

made ceiling, walls, fixtures and lamps were all new and clean. Allowing for the usual deterioration due to dust and use, the data obtained will check very closely with that given in the paper.

In regard to the variation of lighting intensities in different departments of the store, it seems to me that this is less the result of design than of fancy. With the same wattage per square foot rug departments and furniture departments will naturally appear darker than many other departments because of the greater absorption of light. This, together with the fact that detection of fine detail is not essential in these departments, tends to create a feeling that high intensities are not necessary.

In the case of rug departments where rug racks are used, the higher intensities may be obtained by special fixtures and the general illumination in such cases may be kept low. It seems necessary in the sale of oriental rugs to create an atmosphere which resembles the eastern setting of the rugs, and this of course means very dim lighting. The idea seems to prevail also that the same thing is true in regard to lighting for all rugs. I believe, however, that this is largely a fallacy. In the more modern homes of to-day the rugs are seen in a good light and there is just as much reason for good lighting for the display of such goods as for any other line of merchandise.

In regard to furniture departments, polished surfaces are presented on every hand and unless a highly diffused lighting system is used the attempt to cut down the glare results in the use of low candlepower lamps. The absorption of light is very great in such departments also as in the case of rug departments, thus often giving the general impression of being lighted to a much lower intensity than other departments of the store. The power of example is strong, and if any store with a reasonably good standing has departments lighted in this manner other stores in carrying out their lighting schemes are impressed with the general effect and follow this example in their own cases. There is no question, however, that by the use of a well diffused lighting system increased illumination at least to a par with that of other departments will be justified by resulting sales. Human nature does not differ materially when purchasing furniture or rugs to what it does when purchasing any other kind of merchandise. The people want to see what they are getting, and a well lighted

salesroom for rugs or furniture will justify its slight additional expense.

I would very much like to see a further study made of department store lighting in all its aspects.

W. F. LITTLE: Mr. Murphy asks what method was used in making the determinations of illumination in the stores. Wherever the illumination was sufficiently uniform, but few measurements were taken. On the other hand where a considerable variation was found, enough measurements were taken at counter level to secure fairly representative average figures. As stated in the paper, no effort whatever was made to secure anything but average intensities at counter height.

Mr. Murphy's question is answered in previous statements, namely, the ratio of upward to downward flux has been estimated from tests of similar units.

The discussion brought out by Mr. Murphy indicates the importance of further study along this line, and it is the author's hope that such will be forthcoming in the near future.

NORMAN MACBETH: Will Mr. Little indicate on the table just which is the winter and the summer months, and also tell us how many readings were taken? I was in a department store here a few weeks ago where the manager told me that all their case lighting was taken off in the summer time and the lamps taken out of the sockets. He was not quite sure whether it was on the basis of light or heat.

W. F. LITTLE: Tests A, B, C and D were made in the summer; E, F, G and H in the winter. The management of several of the stores objected to measurements being made in the summer, for the reason that the general level of illumination in their stores was considerably lower than the average. On the other hand, in every instance full illumination was available and measured. In our survey we started by taking a number of readings for each bay, but found after a careful consideration of the data that three readings, one under the fixture, one half way between the fixture and the edge of the bay, and one at the edge of the bay would give very repre-

sentative values. The reading at the edge of the bay was multiplied by 16, the half way reading by 8, and the center reading by 1. The summation of these values divided by 25 was used as the average of the bay. With the type of fixture used in most of the stores, this method proved quite satisfactory.

In making our survey we advised the store management that the names of stores in connection with the tests would not be given, so that we do not feel at liberty to give out this information.

J. B. TAYLOR: Is any distinction made in the measurements between the horizontal illumination and vertical on the side wall? It strikes me that in all this work altogether too little attention is paid to the direction of illumination. If it is a rug you are looking at the horizontal illumination is sufficient but with some classes of goods the horizontal illumination does not do at all. You must have a fair amount of light from the side to see it. If the light all comes from overhead it casts a shadow on what you are looking at.

W. F. LITTLE: As the survey was for the purpose of establishing the general level of horizontal illumination, no other values were secured.

C. F. SCOTT: I went into a large department store a short time ago and made a general observation of the illumination. The lower floor was very large. It had white ceilings and numerous rows of large square posts which were white. The illumination was by large white spheres and everything seemed to be a glare. There were no contrasts and no direction where the eyes were relieved. Presumably the illumination on the counters was about right in intensity, but the eyes were so affected by the strong incoming light from all directions they were not in good condition to see the things which were there to be seen. On other floors there were bell-shaped reflectors throwing the light down and not horizontally into one's eyes.

These remarks may be a little aside from the subject matter of the paper, but they indicate some of the factors which are important in a matter of this kind.

NORMAN MACBETH: In Table II, what is the approximate ratio of the upward or downward flux that would be taken, from your general knowledge?

W. F. LITTLE: The values shown in Table 2 of the ratio of upward to downward flux are taken from our experience with similar types of fixtures.

L. C. PORTER: I firmly believe that the primary object in store lighting, as has been expressed before this evening, is to make the store bright and attractive. The secondary object is to get plenty of light on the goods. Analyzing the type of units to improve the appearance of the store has brought me to believe that the good old-fashioned bulb which gives good diffusion is about as good as anything on the market. It is true the old-fashioned bulb emits a lot of light flux to the side and does not get it right down to the goods in the most efficient manner possible, but that light which goes to the side makes the walls and ceilings quite bright and makes the store appear most attractive. Now one feature that enters into consideration is uniformity of illumination. If you turn to Table III you will see that it just happens in this one case that the best ratio between maximum and minimum is from the clothing unit. That is to be expected. When you have a white ceiling, white walls and a unit which gives out a good distribution of light you have got more or less of a large space and the uniformity of illumination is almost as good as you can get. We get about 40 or 45 per cent. of the flux to the working plane, which is considerably higher than the other figures. This all bears out the viewpoint that I have gained more or less from observation, that the best proposition for a large store lighting is some good white glass, diffusing-ball or another shape if desired, with color modified in the lamp itself or by some auxiliary inside the globe.

J. N. ADAM: I would like to ask Mr. Little if his survey included the show windows of these stores. If it does not I would like to ask him if he has the intensity of the show windows of these stores.

W. F. LITTLE: The survey did not embody any tests of this character.

A. L. POWELL: At various times I have given quite a little thought to store lighting and these figures confirm some of my convictions. A few years ago the policy of getting the light on the goods in the most efficient manner was heard on every hand. In other words the use of direct lighting was strongly urged.

The primary object of store lighting, as has been expressed before this evening, is to make the store bright and attractive. The secondary object is to get plenty of light on the goods. With this in mind, if one analyzes the subject to determine which type of unit makes the store appear best, he arrives at the conclusion that the good old-fashioned enclosing globe of white glass which gives adequate diffusion is about as satisfactory as anything on the market.

It is true that it emits a lot of light flux to the side and does not get it down to the goods in the most efficient manner possible, but that light which goes to the side makes the walls and ceiling quite bright and the store most attractive.

One feature which must be considered is uniformity of illumination. In Table III it will be seen that in the cases cited the best ratio between maximum and minimum is with the enclosing unit. This is to be expected. With a white ceiling, white walls and a unit giving a symmetrical distribution of light, the room becomes more or less of a large Ulbrich sphere and the uniformity of illumination is almost as good as can be obtained.

As to utilization according to this table about 40 per cent. of the flux reaches the working plane which is considerably higher than some of the other figures.

The enclosing unit need not be spherical in shape unless so desired, for a considerable variation in contour does not materially effect the distribution. A distinctive shaped globe could be obtained of any decorative period in keeping with the store. Color modification of the light can be made in the lamp itself, a special blue glass bulb screening out those rays which are too predominant for color comparison. If clear glass lamps

are employed and it is desired to modify the illumination, the globe itself can be made with a casing or lining of a suitable bluish color.

In connection with a recent investigation, the writer recently collected data on the lighting equipment of about one hundred and twenty-five department stores all over the United States. It is interesting to note that the average power consumption per unit of floor area of all these examples is very close to the value given in the paper, namely, 1 watt per square foot.

AN INDIRECT LIGHTING SYSTEM IN A TEXTILE PLANT.*

BY GEORGE WRIGLEY.

Synopsis: For obvious reasons, it is frequently desirable in lighting industrial plants to use a small number of large units rather than many small units, provided uniform illumination without excessive glare can be obtained. With direct lighting reflectors the size of unit is limited by such physical features as ceiling height and machinery spacing. This paper describes a system embodying the use of the largest approved size high efficiency incandescent lighting unit, arranged to give the best possible working conditions for the operatives.

In the older type textile mill buildings of slow burning, timber construction, equipped with mechanical or large group motor drives, the obstructions and dirt deposits due to belts, together with the low reflecting value of the ceiling surface made the direct lighting system practically imperative. The new construction of reinforced concrete with unobstructed ceilings of permanently white surface, and the elimination of belts through individual motor drives allow an entirely different treatment of the artificial lighting.

At least fifteen years ago a system of indirect lighting, with inverted arc lamps, was tried in some of the English textile mills, but did not secure extended approval and probably proved unsatisfactory because of the troublesome maintenance of the arcs. The development of the larger size gas-filled incandescent lamps has provided a unit which when properly installed is ideal for indirect lighting service.

In a textile plant the preparatory processes involve the circulation and deposit of quantities of lint and dust. In the spinning and weaving processes this occurs only to a limited extent. While there is some objection to the indirect units in the preparatory departments, this objection is of no serious consequence in the other departments, especially if means are provided for keep-

* A paper prepared for the 1916-17 Correspondence Convention of the Illuminating Engineering Society, and circulated among members of the Society and others who were thought to be interested.

ing the lint from direct contact with the high temperature lamp bulb. The processes in the preparatory department are of such a nature as not to necessitate eye strain.

When the Republic Cotton Mills, at Great Falls, S. C., decided to build their No. 2 Plant, the owners requested that the indirect lighting system be used if practicable, especially as it was planned to operate this plant on both night and day runs. This mill is housed in a modern building of reinforced concrete construction three stories in height and with over-all dimensions of 398 ft. by 131 ft. (121 by 40 m.) Small group-drive motors with belts are used in the preparatory departments and individual motor drives are used in the weave room and the spinning room. This plant is designed to manufacture cotton print cloths and does not finish or print the product.

A fixture suitable for use with either a 500- or a 750-watt gas-filled incandescent lamp was designed, and the approval of the Insurance Underwriters obtained for using this unit in the weaving and spinning departments on the second and third floors, respectively. Direct lighting was adopted for the preparatory departments on the first floor.

The units as finally installed have a capacity of 500 watts and each contains a single lamp. The units are installed on rectangles measuring 22 by 26 ft. (6.7 by 7.9 m.), a total of 572 sq. ft. (54 sq. m.), an equivalent of 0.874 watt per square foot. The fixture consists of a steel shell bowl enclosing a glass bowl with spiralled mirror reflecting surface, and a cover bowl of clear, heat-resisting glass. The cover bowl projects beyond the edge of the lower steel bowl, leaving an air space for ventilation. Cooling air passes through this opening, down between the steel bowl and the reflector, up through an opening in the bottom of the reflector, past the lamp and out at ventilating openings near the fixture stem. The fixtures are suspended by rigid conduit with the cover bowl 42 in. (106 cm.) from the ceiling, and approximately 8 ft. (2.4 m.) above the average working plane.

The lighting effect obtained is very satisfactory, and the working visibility of a high order. In comparison with direct lighting on similar work, eye fatigue is noticeably lessened.



Fig. 1.—General view of mill.



Fig. 2.—Warper room by artificial light.



Fig. 3.—Weave room by day light.



Fig. 4.—Weave room by artificial light.

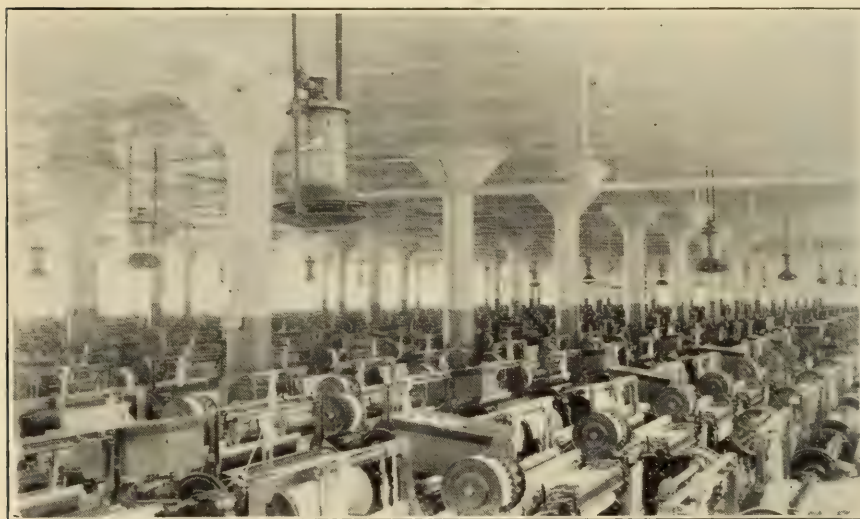


Fig. 5.—Weave room by day light.

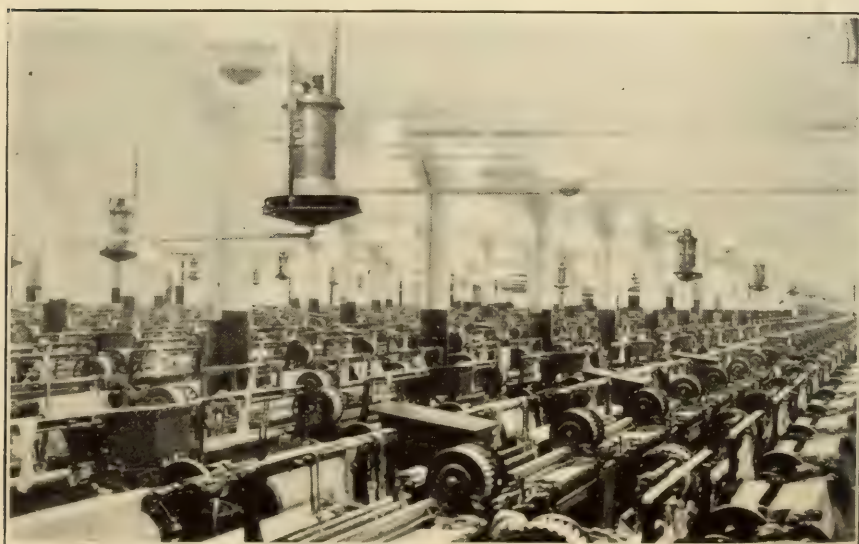


Fig. 6.—Weave room by artificial light.

In consideration of the results obtained, together with the low cost of power, amounting to approximately 0.65 of a cent per kilowatt hour, the slight increase in power consumption over direct lighting practice is of no serious consequence.

To some extent the photographs show the absence of hard shadows under the machines, the details of machinery and the yarn in process of manufacture.

ABSTRACT—AN ASPECT OF LIGHT, SHADE,
AND COLOR IN MODERN WARFARE.*

BY M. LUCKIESH.

The subject was treated from the viewpoint of the theory and practice of camouflage. Camouflage is a modern term for an old art which has been practiced by nature long before the advent of man. Animal coloration is an important factor in the Darwin theory of evolution or of the survival of the fittest. In this great war the practice of camouflage is highly developed and we must consider an aspect of the science of light, color, and vision which is not ordinarily considered by the artist. Excellent work has been done on animal coloration and excellent analyses are available. One of the chief principles of animal coloration is broken color and pattern. An object of solid color can not be easily concealed in natural environments. Natural camouflage involves general hue, pattern, countershading, mimicry, mobile color and pattern, etc. Black areas on animals may simulate shadows. Pattern may be used to simulate the background, to alter the appearance of the outline of the animal, to bewilder the enemy, etc. Most animals are counter-shaded, being of higher reflection—factor underneath to compensate for the lower illumination intensities on these areas. Some animals imitate by their form or posture inanimate objects or other animals that are dangerous. Some animals change their coloring with the season, others almost momentarily. Thus from nature the camoufleur may learn much and the lighting expert is equipped with knowledge of the other scientific aspects.

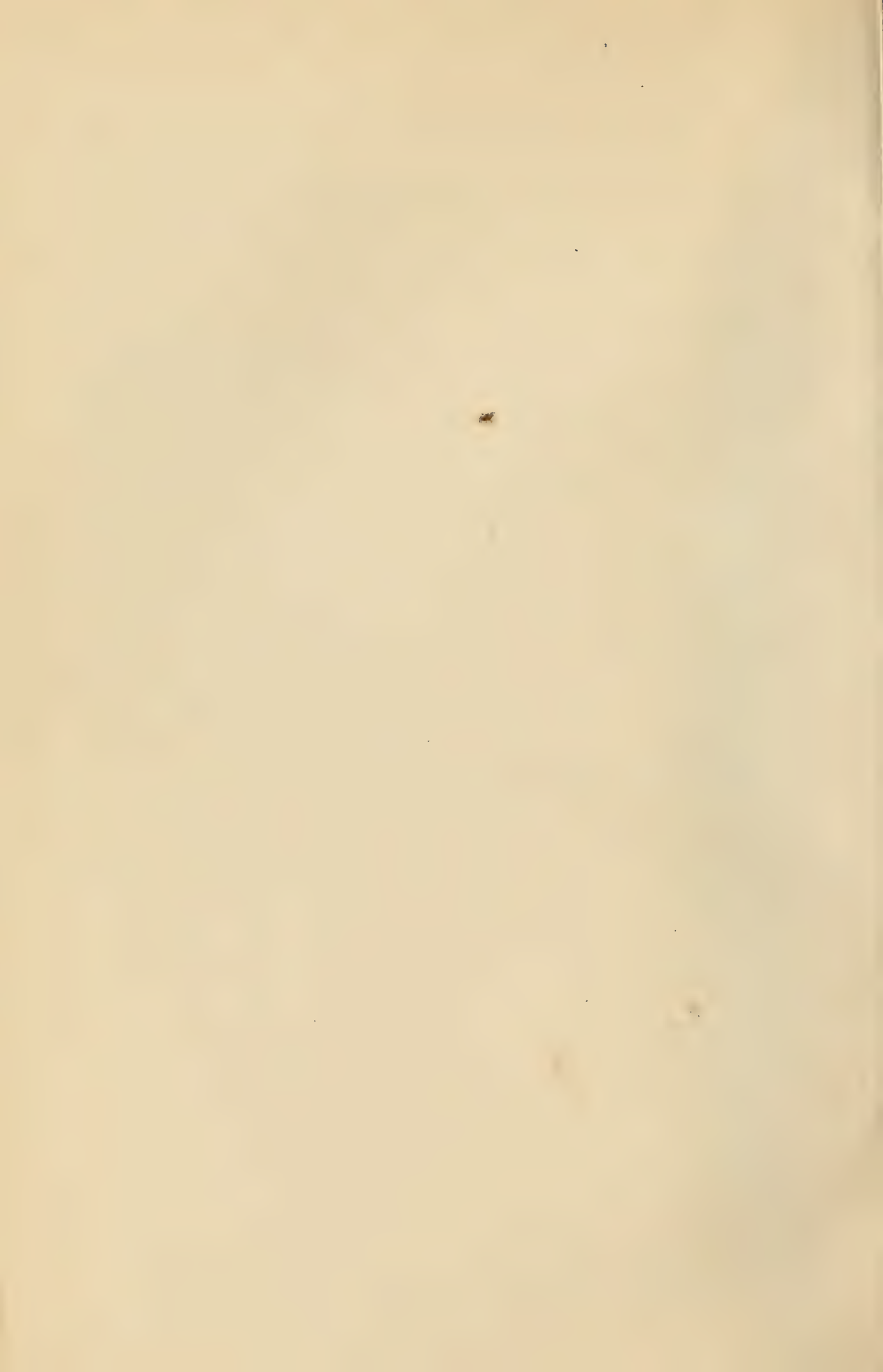
About fifty lantern slides were shown which illustrated the aspects of color science involved, the variation in nature's lighting, the practice of camouflage, the theory and practice of aerial photography which is the enemy of camouflage, etc. On overcast days the problem is simplified but on sunny days the shadows present difficulties which are met by effecting other "shadows" and therefore confusion, by special contours of objects in order to minimize shadows, and by other expedients.

The artist usually deals with color from the subjective stand-

* Abstract of an address by M. Luckiesh, delivered before the New York Section on March 14, 1918.

point and the importance of imitating the surroundings by means of pigments which are spectrally the same was emphasized. For example, the chlorophyll green of vegetation appears green but exhibits a deep red band in its spectrum. A green paint which would ordinarily be mixed to match this green subjectively would not exhibit the red band spectrally. When such an artificial green is viewed through a deep purple filter (such as methyl violet) or a dichroic green filter it appears a dark gray but through these filters the chlorophyll is a brilliant red. By means of spectral analysis, pigments can be mixed to simulate the desired color spectrally. Attention was directed to experiments made by the speaker before the war on the use of filters for defeating camouflage or for revealing objects such as soldiers by augmenting the contrast.¹ By means of filters, we apparently produce eyes which in effect are the same as though they differed in spectral sensibility. The many photographic plates of different spectral sensibilities also emphasize the importance of the spectral viewpoint toward camouflage. The aspects which the earth presents when viewed at heights as great as 2 miles were described from personal experience in studying this phase. Marine camouflage and other aspects were also treated. The address emphasized the extending breadth of the field for the lighting expert as he extends his knowledge of the facts of light, vision, color, and the appearances of objects as influenced by their coloring and by the distribution and quality of light.

¹ M. Luckiesh, *Color and its Applications*, pp. 160, 272, etc.



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ROCKETS AND ILLUMINATING SHELLS AS USED IN THE PRESENT WAR.*

BY A. BERGMAN.

Synopsis: Rockets and illuminating shells are extensively used in modern warfare. They function not only in revealing enemy movements, but also in laying down light barrages behind which it is impossible for the enemy to see. The usual rockets are self propelled as are the common spectacular fireworks. The present war has introduced illuminating shells which are fired from trench mortars, rifles, and heavy pieces. These shells, consisting of tube, base, top, star and parachute, are fired at velocities of the order of 2,700 ft. (824 m.) per second. They may be gauged to ignite at any distance from 200 yd. (183 m.) to 4 miles (6.45 km.) and to burn from 3 to 30 seconds. Curves are included showing the relations between candlepower and time of burning.

The value of rockets in war time was appreciated very early in history, but they were used practically only for signalling purposes up to very recent date.

All night long, and along the whole western front rockets or star shells are sent up in an endless stream; the purpose being, of course, to enable observers to discover any movements of the enemy, his patrols or whatever activity he might attempt in the dark.

The most effective point from which to illuminate a given area is from directly above, although if the enemy is out in the open, for example, in the act of attacking, it is often of advantage to

* A paper presented before a meeting of the New York Section of the Illuminating Engineering Society, New York, April 11, 1918.

attempt to place the light behind him, as he will then present a splendid silhouette target against the illuminated background. The light will then also be further away from our own trenches, leaving them in greater darkness.

Another novel use for rockets and illuminating shells is to use them as a "light barrage," behind which it is possible to execute movements without fear of having our activities discovered by the enemy. A light barrage is produced by causing a very large number of lights to burn continuously between the enemy's and our own trenches. It is impossible to see through this curtain of light and the only answer to this that the enemy can give is to blindly shell and sweep the terrain with rifle and machine gun fire in hope of hitting something.

ROCKETS.

The rockets used are principally of two different kinds, *i. e.*, the ordinary, well-known type that sails along ahead of a tail of fire, and which finally bursts in a brilliant flash, illuminating a large area for a few seconds.

Later improvements of this type of rockets provides a star that does not consume itself in a single flash, but which burns with a brilliant light during the few seconds it is falling to the ground.

The second type of rockets is also operated on the same principle, but in its head it also carries a parachute to which the star is attached. Through this arrangement it is possible to keep a brilliantly burning star suspended in the air for a comparatively long time, which is generally fixed to be about 30 or 35 seconds.

ILLUMINATING SHELLS.

In addition to rockets, "illuminating shells" are used; the fundamental difference being that while the rockets are propelling themselves through the air, the illuminating shells are fired from a suitable weapon, and the development of this shell has now reached such a high degree of perfection that different types of them can successfully be fired from rifles, trench mortars and field as well as naval guns.

It is particularly remarkable that it is possible to successfully fire illuminating shells from the powerful naval guns. It must

be noted that by its nature a part of the make-up of such a shell is of a flimsy material such as the parachute, which in these shells are made of silk with its attachments of cords, etc. These shells are fired with a velocity of over 2,700 ft. (824 m.) per second and the chamber pressure required therefore is nearly 20,000 lb. per sq. in. (1,400 kgm. per sq. cm.). A standard time fuse causes the shell to operate at any point up to several miles. The burst ignites and ejects the star with the parachute which opens up and keeps the burning star suspended until it has consumed itself.

This performance is undoubtedly the triumph of pyrotechnics to date in this direction.

GENERAL DESCRIPTION OF ILLUMINATING SHELLS.

The five principal parts employed in the construction of illuminating shells are as follows:

The *tube*, which forms the sides or body of the shell and which is made of heavy paper tightly rolled in many layers and glued together, or when the shell is intended for long range shooting it is made of fiber or metal.

The *base*, made of wood or metal in which generally a fuse and a bursting charge are located.

The *top*, which is simply a disc of wood, fiber or any other suitable material and which is so attached that it can comparatively easily be forced out from the inside.

The *star* is a powerful illuminating compound made of various chemicals such as barium, nitrate, potassium perchlorate, powdered aluminum, magnesium, etc. These are carefully mixed and rammed hard into a container of suitable material.

This container has a top and side, usually cylindrical in form and is filled to within about $\frac{1}{8}$ in. (0.32 cm.) of bottom with the illuminating composition. The remaining space is used for an ignition charge such as finely ground black powder called "mealed powder."

The *parachute*, made of paper or silk and so packed together as to readily open when expelled.

THE FUNCTION.

When the illuminating shell is fired, the fuse starts burning either from the flash of the propelling charge or through the action of a mechanism operated by the shock of the discharge.

When the spark reaches the termination of the fuse it ignites a bursting charge, which upon exploding ignites and expels the star and the parachute forcing out the top of the shell.

The velocity of the star acts upon the parachute in such a manner as to open the same, whereupon it floats, suspended in the air until it has consumed itself.

MAIN TYPES OF ILLUMINATING SHELLS.

By introducing a time fuse that can regulate the bursting point of the shell, the star can be released and ignited on any desired point in the shell's trajectory. This makes it possible to utilize the same shell regardless of the distance from the gun to the object it is desired to illuminate.

There are, however, so many other conditions to be considered that, although the drawback of a multiplication of ammunition is fully recognized, it would serve to increase the efficiency of an army if say three different sizes and types of illuminating shells having the following characteristics were supplied:

To be fired from	Max. range
1. Rifle (as rifle grenade).....	200 yards (183 m.)
2. Trench mortar.....	1 mile (1.6 km.)
3. Field or naval gun.....	3 to 4 miles (4.8 to 6.4 km.)

RIFLE ILLUMINATING SHELL.

Such a shell should be fired by the same method as a rifle grenade and could be constructed very simply. A time fuse that could be regulated would hardly be necessary, but could easily be provided. The ignition of the fuse could be accomplished either through a channel in the rod or by using a plunger.

An illuminating shell of this kind is not fired through the bore of a gun and does not receive such a severe shock as would be the case if a longer range was sought, and could be made with the usual casing eliminated, that is, it would not be necessary to fire a metal tube, from which later the illuminant with its parachute was ejected. This illuminant could be packed in a cartridge of enough strength to itself form the body of the projectile, to the head of which can be attached a pointed metal hood, inclosing a parachute, the bottom end of which can be provided with a metal base holding the time fuse and to which the cord and wings are attached. At the proper moment this bottom base with attachment can be blown off with a small bursting charge,

which at the same time ignites the illuminant and releases the parachute by also detaching the metal hood.

Signal lights can also be substituted for the illuminant and so constructed that the colors could be interchanged just prior to their use and made to burn in the desired rotation.

TRENCH MORTAR ILLUMINATING SHELL.

An illuminating shell with a range of 1 mile (1.6 km.) to be fired from a trench mortar required a materially stronger construction than would be necessary in a rifle illuminating shell.

A range in excess of 1 mile (1.6 km.) can be obtained by this type shell by increasing the powder charge, but for various reasons that will be mentioned later, it is advisable to limit the range of this type to about that distance.

The satisfactory functioning of the parachute is one of the most important points in the construction of an illuminating shell, and one of the factors that make it advisable to limit the range of this type to about 1 mile. The parachute should be as large as practical so as to prevent the star from descending too rapidly. It should, however, be noted that since the star becomes lighter as it is consumed the speed of the descent becomes correspondingly less and finally becomes hardly noticeable.

The larger the parachute, however, the greater is the strain put on it when it is made to open in the path of the shell's trajectory where the velocity is greatest. Hence, if it is desired to utilize the full benefit of a time fuse, it will be necessary, if the maximum range is made very long, to use a parachute so small as to decrease its general efficiency. This difficulty could, however, be overcome by changing the propelling charge with the range required, but this is a drawback that if possible should be avoided.

The above is the main reason for advising a mile (1.6 km.) as the limit for this type of shell as in order to make the parachute stand the strain of opening say at 200 yd. (183 m.) when its container has an initial energy capable of carrying it a mile (1.6 km.), it has been found necessary to develop means by which the opening of the parachute, after it has been ejected from its case, is delayed until the velocity of the star is retarded.

ILLUMINATING SHELL TO BE FIRED FROM FIELD
OR NAVAL GUN.

For ranges of more than 1 mile (1.6 km.) it is advisable to so construct the illuminating shells that they can be fired from a standard field or naval piece such as the 3 in. (7.6 cm.) or larger guns.

Radical changes in the design of such shells from those above mentioned is necessary, but the fundamental principles are the same, as the problem to be met remains the same only in a greater degree, but they are met by enlarging the means to counteract them.

The size, shape and preferably also the weight should coincide with standard shells, but it is not necessary or even advisable to utilize standard shells, as these are designed to be used for a different purpose. Furthermore, they are more expensive shells than are necessary for the purpose of carrying an illuminant and parachute until it is to be ejected.

A steel tubing fitted with a standard copper band with the inside walls parallel and having enough wall thickness to give the necessary strength and required weight, serves the purpose admirably. A standard or modified head with a standard 21-second fuse fitted to this tube. The bottom is made in a separate piece and so attached that at the desired moment, it can be blown off without scattering or putting undue pressure on anything else. With the bottom off, the illuminant, parachute, etc., is ejected backwards with enough force to greatly counteract the velocity at which it was traveling, thus helping in relieving the strain on the parachute.

It is necessary also in this type of shell to take into consideration centrifugal force and its action on the operation of the parachute. Provision for this must be made in the packing and by attaching sufficient cord or chain of suitable material adequately fitted with swivels, between the illuminant and the parachute.

GENERAL NOTES.

In determining the length of time the illuminant shall be made to burn, it should be borne in mind that there is little advantage in producing an illuminant that will burn for an extended period, except possibly in coast defense work in shells with a very long

range, as even a moderate wind will, during a minute, carry the star a considerable distance.

Furthermore, everything else being equal, the more rapidly an illuminating compound is allowed to burn the more brilliant will be the light.

Hence, it is better not to use an illuminating compound that will burn for the longest possible time, but to limit the time element to a reasonable degree and to fire the illuminating shells so much more frequently.

The parachute should be made of silk. This fabric combines strength, light weight, ability to resist deterioration indefinitely when sealed in a shell, provided proper precautions are taken, and the quality of not becoming so creased after long packing that the parachute might fail to operate correctly.

The parachute itself as well as the cords attached to it may be fireproofed as there is the possibility that they otherwise might be ignited by a spark.

CANDLEPOWER DEVELOPED.

To determine the values of flares for illuminating purposes, the candlepower developed should be measured and the time of burning noted. The values obtained should be reduced; first into candlepower-seconds and then into candlepower-seconds per cubic inch of composition. Only after obtaining these values is it possible to intelligently compare flares for the purpose of determining which develops the most candlepower. For example, we have two flares of the same length and diameter:

No. 1 burns up in 4 seconds, developing at an average 354,000 cp.

No. 2 burns up in 30 seconds, developing at an average 47,200 cp.

It is difficult or impossible to state which of these two illuminants is the better, without reducing their performance into candlepower-seconds when it will be found that:

No. 1 develops $4 \times 354,000 \text{ cp.} = 1,416,000 \text{ cp.-s.}$

No. 2 develops $30 \times 47,200 \text{ cp.} = 1,416,000 \text{ cp.-s.}$

That is, the two flares developed the same amount of light in the aggregate, although No. 1 generated it seven and one-half times as fast as No. 2. (As these two illuminants were of equal size it was not necessary to reduce the values to candlepower-seconds per cubic inch.)

The above is more fully exemplified in the following table and in Fig. 1, which give the actual data obtained from photometric tests of eleven lights, the illuminating elements of whose composition were identical, differing only in the time in which they were allowed to consume themselves.

TABLE I.—CANDLEPOWER AND TIME OF BURNING.

Diameter of illuminants 1.94 in. (4.92 cm.).

Burning surface 2.95 sq. in. (19 sq. cm.).

No.	"A" Total length of light ¹ inches	"B" Total burning time seconds	"C" Average candle- power	"D" Burning time per inch seconds ² $\frac{B}{A}$	"E" Cubic inches of com- position ³ $A \times 2.95$	"F" Total candle- power seconds $B \times C$	"G" Candle- power seconds per cu.in. ⁴ $\frac{F}{E}$
71	2.44	16	213,000	6.55	7.2	3,400,000	472,000
72	2.	10	269,000	5.	5.9	2,690,000	456,000
77	2.25	22.5	143,400	10.	6.65	3,210,000	482,500
78	2.12	16.	186,500	7.55	6.25	3,000,000	480,000
92	2.25	35.	89,700	15.5	6.65	3,140,000	472,500
100	2.	34	79,800	17.	5.9	2,710,000	460,000
103	2.37	35	96,700	14.75	7.	3,385,000	484,000
110	2.37	31	108,800	13.1	7.	3,375,000	482,500
111	2.37	32	113,300	13.5	7.	3,630,000	520,000
112	2.63	32	115,150	12.2	7.75	3,680,000	475,000
113	2.5	28	132,300	11.2	7.4	3,700,000	500,000

One had ignition charges resp. 0.62 (1.5 cm.) and 0.87 in. (2.21 cm.) long, which burned 4 and 5 sec. These values are not included in above data.

The candlepower-seconds per cubic inch developed by these illuminants showed only slight variation, although the time of burning varied from 5 to 17 seconds per inch (2.54 cm.) and the candlepower from 269,000 to 79,800.

The average candlepower-seconds per cubic inch was about 480,000, which value can be used in fixing the value of this particular light.

The point in the above which in particular is of practical useful interest is the deduction derived, proved by actual tests, that a fixed volume of a fixed composition will develop a fixed number of candlepower-seconds regardless of its speed of burning. It is of course understood in considering this point that no changes

¹ Multiply by 2.54 to obtain length in centimeters.

² Divide by 2.54 to reduce burning time per centimeter.

³ Multiply by 16.4 to obtain cubic centimeters of composition.

⁴ Divide by 16.4 to obtain candlepower-seconds per cubic centimeter.

in the percentages of the various chemicals used in making up the composition be permitted in order to cause the fluctuation. The time of burning, in the eleven sample illuminants used by us, was regulated only by treating the composition by various methods.

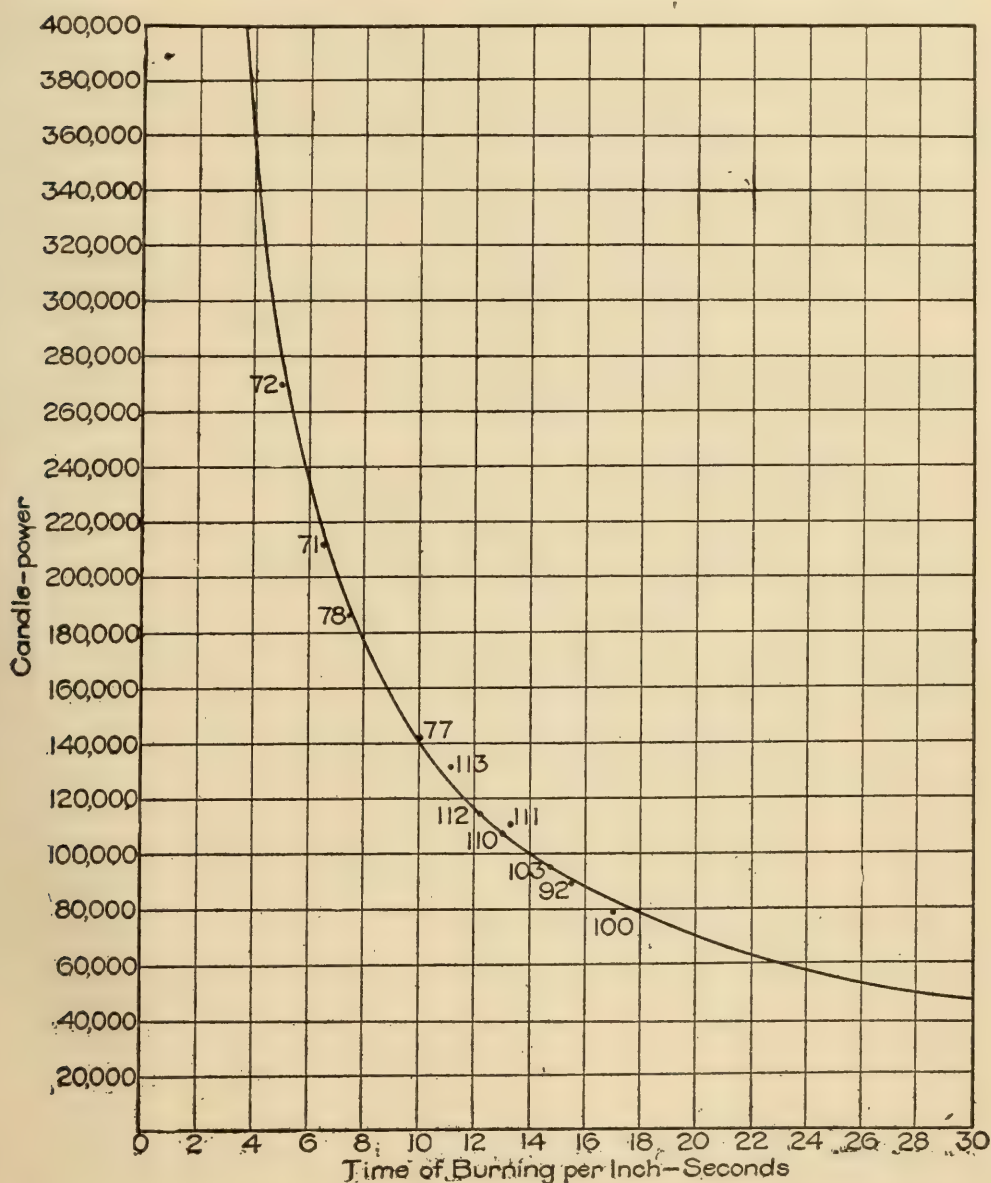


Fig. 1.—Relationship between candlepower and time of burning. Calculated from data obtained through photometric tests of lights, having a burning surface of 2.95 square inches, and which lights developed at an average 480,000 candlepower seconds per cubic inch of composition.

In making a study of the chart, Fig. 1, it was noted that the lights giving the highest and the lowest candlepower showed a

tendency to fall below the curve, while two of the lights at the center came above the curve.

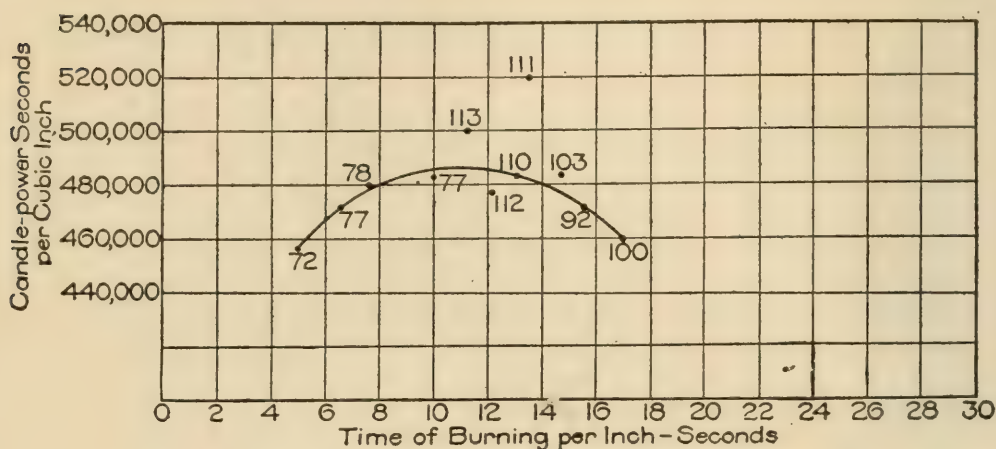


Fig. 2.—Candlepower second developed per cubic inch of composition; burning surface of illuminants—2.95 square inch.

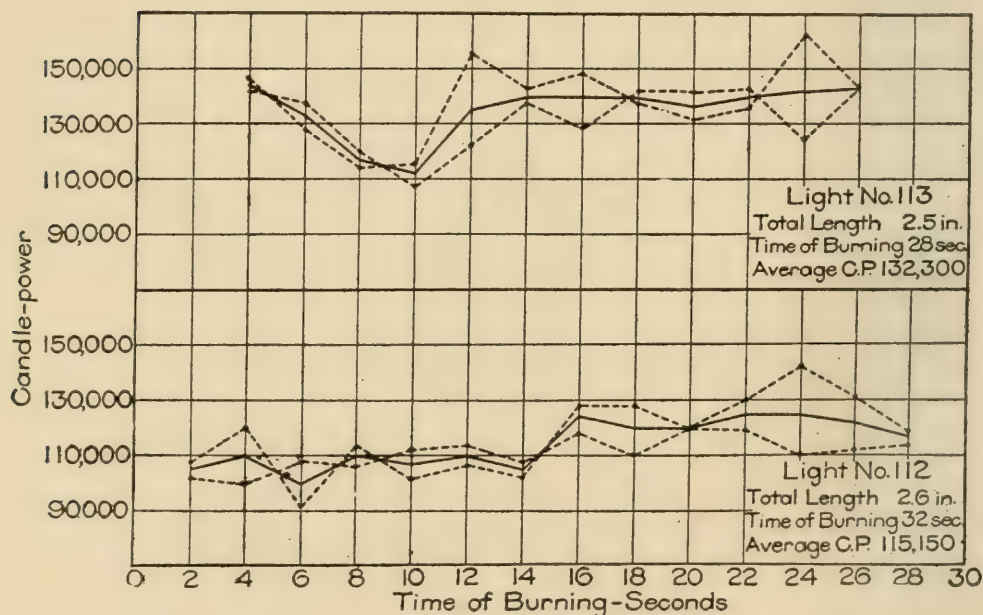


Fig. 3.—Degree of fluctuations in candlepower.

This led to the plotting of Fig. 2, which shows the candlepower-seconds developed per cubic inch (16.4 c.cm.) of composition in connection with the time of burning of the flares, and the plotting seems to indicate that there is a slight tendency towards decrease in the candlepower-seconds developed when the time of burning increases or decreases beyond a certain point. The maximum

efficiency appears to be when the flares are made to burn at the rate of between 10 and 12 seconds per inch (2.54 cm.). The variation, however, is so slight that it is more of academic than of practical interest, but it might be a point to be taken under consideration if flares are to be made to be burned for an abnormally long or short period. The data we have on this point, however, is insufficient to determine anything definitely.

We also wish to point out that all our data is obtained from illuminants having a burning surface of 2.95 sq. in. (15.5 sq. cm.) and we have had experience that might indicate that lights with a smaller burning surface would develop less candlepower-seconds per cubic inch. If this proves true it is probably due to the fact that less heat is generated, which might result in less perfect combustion.

Fig. 3 is attached only to show the comparatively slight fluctuations in the lights we have now succeeded in producing. The lights referred to on this sheet were of the same lot as fired at Sandy Hook on September 11th, when it was demonstrated that they were suitable to be used in our illuminating shells.

DISCUSSION.

L. M. WALDO: As Mr. Bergman has pointed out, the illumination of the field is almost continuous, and some of Mr. Bergman's colleague companies have been devoting themselves not so much to the question of these aerial flares, but to flares which are used for indicating the place to which the aviator must return. Those flares are usually called position lights. They are of equal power and they are placed along the service line, so that distant aviators can see these lights, even 30 and 40 miles away, and can find an easy way home. The duration of flares of that description, must be somewhat longer than the flare which have been shown this evening. They run a minute, two minutes, sometimes as high as eight minutes. In connection with all flares of that class, the question of smoke is almost vital. Some flares have been designed in which the transmission of light is 71 per cent. through the smoke. Of course that gives you an additional value.

Flares are generally tested under the protection of a smoke-stack anywhere from 70 to 80 feet high, so that the operators can be protected from the smoke, which is very great sometimes,

and if they were tested under actual conditions, it would end in a great deal more efficiency being displayed.

C. E. CRITTENDEN: The distribution of light from these flares is a matter in which there is often misunderstanding. These things are practically flames. The light comes very largely from an extended flame, rather than from a crater, and except for the shadow cast by the base of the flare, the light is practically the same in all directions.

C. O. BOND: In making a hurried calculation just now, it would appear that the cost per candle hour for light is less with these star shells than with wax or paraffin candles.

NORMAN MACBETH: I understand from Mr. Bergman that the effective area is a matter of 600 yards diameter and I assume that that shell burns from the top, so that the maximum is largely in the upper hemisphere and on the horizontal.

A. BERGMAN: It burns from the bottom. Not very long ago we were burning a light up here at the Electrical Testing Laboratory, that gave wonderful candlepower, a beautiful amber colored light, which is not so dazzling as a white light; and therefore preferred by some authorities. The light rays spread in all directions, but it gives, of course, the most illumination straight downwards, when it hangs suspended from a parachute.

NORMAN MACBETH: On the basis of our ordinary cost of lighting service, I believe that this lighting, assuming 50 cents for 150,000 candlepower for 30 seconds, is equivalent to only 5 to 10 times the cost of light produced from our ordinary gas and electric lamps.

L. M. WALDO: A great many thousands of dollars has been spent in determining the rate of combustion of the case and the charge within it. This rate should be identical for both the case and the charge in order to prevent the formation of just these lateral shadows. If you have 200,000 candlepower flare and your case is not consumed at an equitable rate, your candlepower will show great discrepancies. The problem is by no means completely solved. One begins to use the aluminum case and then he finds aluminum cases disappear with unheard of rapidity, and he goes to steel cases, and he gets the same results. It is a very hard thing to float a shell in the air with the mouth downwards.

L. C. PORTER: I have been interested in comparing the candlepower of these flares with the candlepower of searchlights. We had flares here going up to 20,000 candlepower if not higher. We can easily obtain incandescent searchlamps which will go up to 3,000,000 candlepower, but the great difficulty in using searchlights for landing purposes is that you can not always tell where the aviator is. He may be over here or over here or behind you, and the beauty of the flare is that it is visible from any point in the sky, whereas, with a searchlight at long distance, 25 to 30 miles, it would only be visible at the time the aviator happened to be in line with the beam of the searchlight itself. Several ingenious schemes are under development by which the searchlight will cover all sections of the atmosphere at different times, so that the aviator may be able to see the searchlight. I think that this is a much more economical method of lighting than by flares.

MOTION PICTURE PROJECTION WITH TUNGSTEN FILAMENT LAMPS.*

BY J. T. CALDWELL, A. R. DENNINGTON, J. A. ORANGE AND
L. C. PORTER.

Synopsis: The past year has seen the beginning of an extensive introduction of tungsten lamps into the moving picture projection field. The development of lamps for this purpose had its inception in the General Electric Company's Research Laboratory at Schenectady. It has been carried through to the commercially successful stage by the engineers of this and other manufacturers co-operating in the development of incandescent lamps. This account of the development is drawn up by those engineers and rounded out by a representative of the laboratory. This paper covers the historical development of the carbon-arc motion picture projector and points out some aspects of the art of projection that favors the replacement of the arc by the incandescent lamp. The types of lamps used together with illustrations of the auxiliary equipment, and data on the advantages and disadvantages of the several systems form the major part of the paper. An appendix gives some important commercial aspects of the subject.

HISTORICAL INTRODUCTION.

Prior to the development which is treated of in this article, the commercial projection of moving pictures was dependent on the use of the carbon arc almost entirely. In a few very exceptional cases the limelight had to be used; sunlight too may have found a limited application.

A short time after the gas-filled tungsten filament lamp had become an assured success, Dr. W. R. Whitney instigated an endeavor to devise some form of the lamp which might be used for this purpose. The data available indicated that the best line to follow was one which started out from a special lamp made

* A paper prepared for the 1916-1917 Correspondence Convention of the Illuminating Engineering Society. This paper was also presented before the New York Section of the Society on December 13, 1917.

but a short time before for Mr. J. B. Taylor, who was interested in micro-photography.

On the theoretical side, the outlook was fairly good from the start. The then recent introduction of the "gas-filled" principle had caused a jump of some seven fold in the intrinsic brilliancy attainable with tungsten filaments, on a given life basis. The brilliancy of the filament under practical limitations could reasonably be expected to be of the order of 20,000 cp. per sq. in. (30 cp. per sq. mm.).

The crater of the d-c. carbon arc (with cored anode) was well known to have a brilliancy of 84,000 cp. per sq. in. (130 cp. per sq. mm.) almost irrespective of the current strength. The a-c. arc was found, as might be expected, to have a lower brilliancy while the limelight showed a brilliancy which was only of the order of 2,000 cp. per sq. in. (3 cp. per sq. mm.).

It looked as if the tungsten filament possibilities were quite in the arc class, especially if we could contrive to arrange the filament so as to constitute a light source of extension sufficient for the purpose and averaging up approximately to the brilliancy of the filament considered to detail. When this had been accomplished a trial was made in a projection machine, with results which were very encouraging.

The Westinghouse Lamp Company and the Edison & National Lamp Works of the General Electric Company have devoted a great deal of attention to the problem and have now arrived at the commercial stage.

Some brief consideration of the illumination principles underlying projection devices is essential to a proper understanding of this development.¹ Two styles of treatment are applicable in a case of this kind; the one introduces the notion of a ray of light and arrives at quantitative results which are unquestionable if the user is sure of his ground and uses the ray-fiction consistently throughout; however, the process is difficult and success is extremely rare. The other and less popular method answers all questions of light quantity by recourse to the conception of

¹ A more complete account is given in TRANS. I. E. S., p. 768, Vol. XI, 1916.

brightness and simple optical principles; this method is well-nigh infallible and it is the one adopted in what follows.

The simplest projection device is the ordinary camera. Neglecting the minor matter of lens losses the only things of significance in the illumination aspect of the device are the brightness of the object projected and the angular value of the lens opening (the so-called speed or F-number of the lens). This must be somewhat qualified when short exposures are considered, because the average working opening, which is what counts photographically, is less than the full opening of the lens diaphragm owing to the finite duration of the shutter action. The satisfactory camera represents a compromise in the matters of lens speed and shutter design. The higher the "speed" the greater the illumination value, the lower the "speed" (within reason) the easier it is to provide for a well-defined picture. A shutter which does not impose a serious limitation on the effective opening at short exposures calls for much mechanical ingenuity.

The moving picture projector can be regarded as an elaborate camera. The factors in the illumination problem are, (1) the brilliancy of the object, *viz*: the film, (and if we ignore the picture or think only of the clear parts of the film, the brilliancy of the light source is practically identical with this). (2) the *effective* working opening or speed of the projection lens.

As in the case of the camera, the actual diaphragm opening of the lens must be considered, and there is again a shutter which affects the *average* working opening as is evident from simple mechanical and geometrical considerations. In addition to these, however, there is additional restriction of the effective lens-opening in two ways, one of which is determined by the size of the light source, and the other by the angular value of the condenser opening relative to points on the film. This is the reason why the brilliancy of the light source and the gross angular opening of the projection lens do not entirely determine the illumination performance, (neglecting trivial losses). If they did, there would be no such variation of performance as is actually obtained by using d-c. arcs of different amperage.



Fig. 1.—(A) Filament burning with no mirror in place; (B) filament burning with images inserted by properly focused mirror. The action of the mirror with the lamp having two rows of coils is somewhat similar but difficult to illustrate.

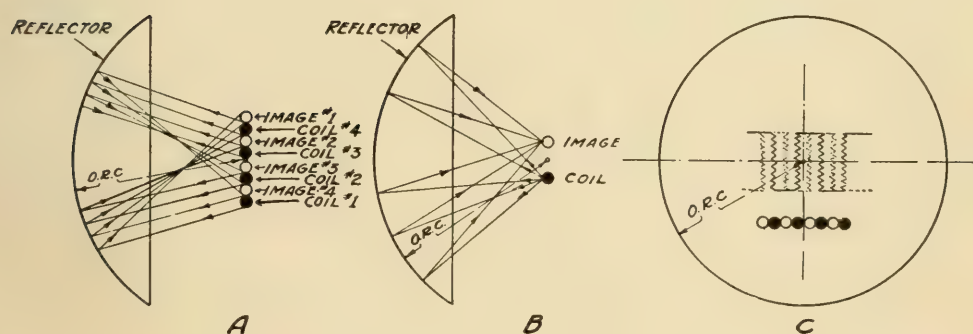


Fig. 2.—Showing general mode of action of spherical mirror used with incandescent lamps, for projection purposes. The action of the mirror with the lamp having two rows of coils is somewhat similar but difficult to illustrate.

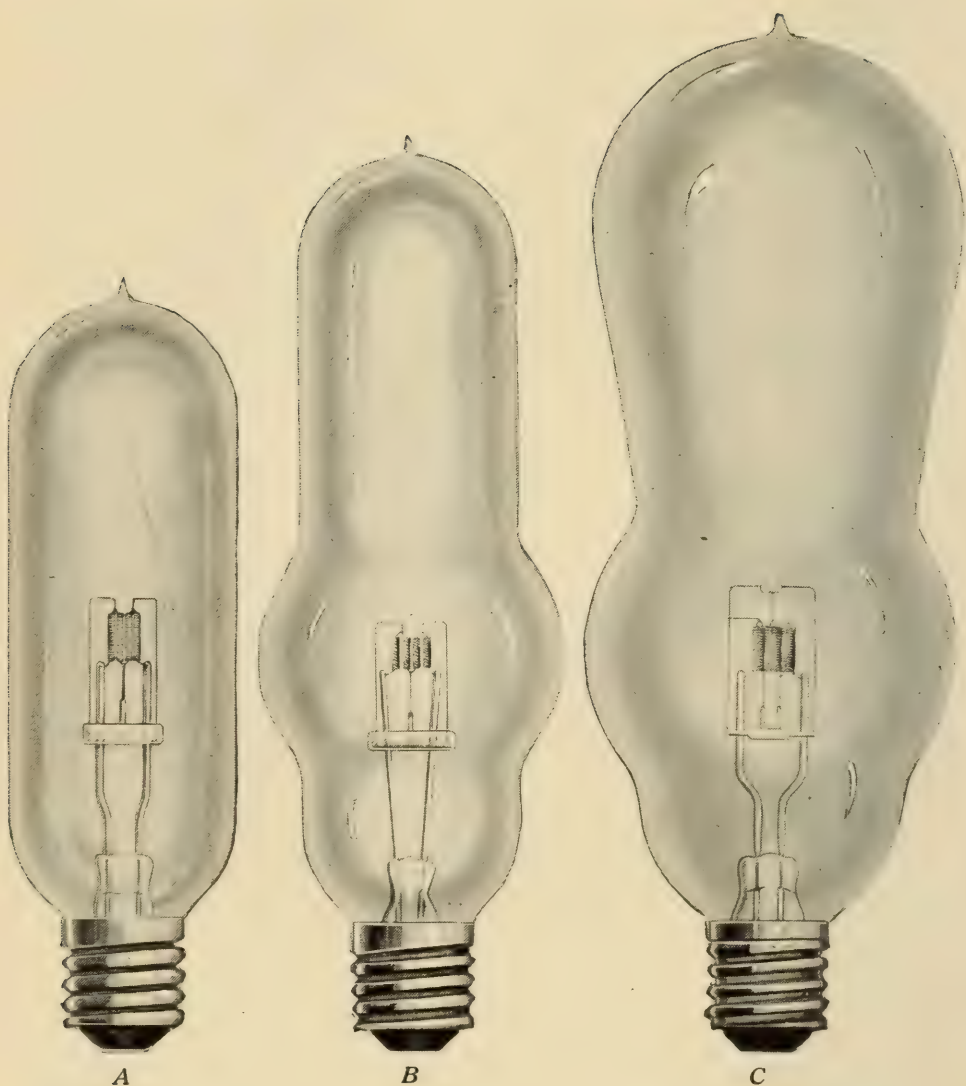


Fig. 3.—Types of lamps used for motion picture projection; "A," 600 watts; "B," 750 watts; "C," 1200 watts. All $\frac{1}{3}$ scale.

Really, the system which is commonly advocated in arc practice imposes a serious limitation on the effective projection lens-opening, and in this case the size and position of the condenser lens are responsible.

Enough has been said to indicate that the tungsten lamp—already in the arc class—can be made to yield results quite comparable with the commercial standards of illumination now obtained with the arc, the only requirement being appropriate optical equipment such as is now available for most classes of theatres.

Since the existing commercial standards of illumination are giving satisfaction to the theatre patrons, it is sufficient for us that we have attained them with the incandescent lamp. What might be accomplished with the arc, if elaborated and tricked out afresh with an improved optical train, does not interest us. The inherent disadvantages of the arc in either a-c. or d-c. form are so marked and so numerous as to constitute a sufficient answer to that question.

As in most matters which involve a great diversity of considerations the choice of a projection outfit does not admit of a single detailed recommendation which can claim the support of all competent judges. The various factors refuse to be reduced to a common denominator and the relative weight which they receive will depend on the judge. To take only one analogy, automobiles of any one class vary greatly in the details of construction, although the technique is well-nigh common property. As we have said, this simply means that the engineers assess the importance of different considerations differently and hence arrive at different compromises in their recommendations.

In our account of the various forms of apparatus we can simply indicate the advantages and disadvantages without attempting to assess the relative importance; each author very naturally holds to his own opinions on such points and discussion would be out of place on this occasion.

THE LIGHT SOURCE.

Technical men who are unfamiliar with lamp design generally seem to assume that the best form to give the tungsten would be a thin plate. There are very weighty reasons against using

such a form; to make this clear would require a discussion of the involved relations of voltage, current, brilliancy and life. It is unnecessary to go into that aspect of the matter because we believe that the filament constructions now used in the lamps *have a mean light-source brilliancy closely comparable with that of the smooth plate* at the same temperature. The sole respect in which a plate has any advantage is in *perfect evenness* of brightness; this is of absolutely no consequence when the proper optical train is used. In all other respects the plate would be woefully handicapped.

The filaments, which are of thick wire, are wound in helical coils of very small pitch and the inevitable separations between the coils are taken care of by a systematic arrangement of a concave spherical mirror mounted behind the lamp. (See Figs. 1 and 2.) Thus the light source may be viewed in any direction which is of practical significance, and it will show an almost unbroken assemblage of filament and mirror image. True the mirror image is appreciably less bright than the filament proper, but it should be remembered that much of the surface seen is substantially brighter than a simple tungsten surface at the same temperature. This is due to the high reflectivity of tungsten and what may be called the "perforated" character of the source.

The mirror serves an additional purpose in that it restores to the filament a very appreciable amount of radiated energy, which would otherwise be wasted; consequently the power consumption is somewhat reduced. To sum up, the mirror confers evenness of source, higher mean brilliancy, and lower wattage.

The lamp bulbs used are specially designed so as to allow of correct placing of the filament with respect to the condenser and mirror, while the screw bases are at the bottom, an arrangement which seems advantageous in every way. Three types of lamps are shown in Fig. 3.

The life-basis on which the moving picture lamps are designed is 100 hours. This makes the lamp renewal cost comparable with the present carbon renewal cost. At present there is no certain method of establishing the *most desirable* life. Combined cost per lumen on the screen for lamp renewals and power is not a safe guide because *satisfactory* screen illumination (from the patrons' standpoint), is of greater importance than the cost

differences involved. The dimensions of the light source are not chosen at random, but are based on careful consideration of the rest of the optical train.

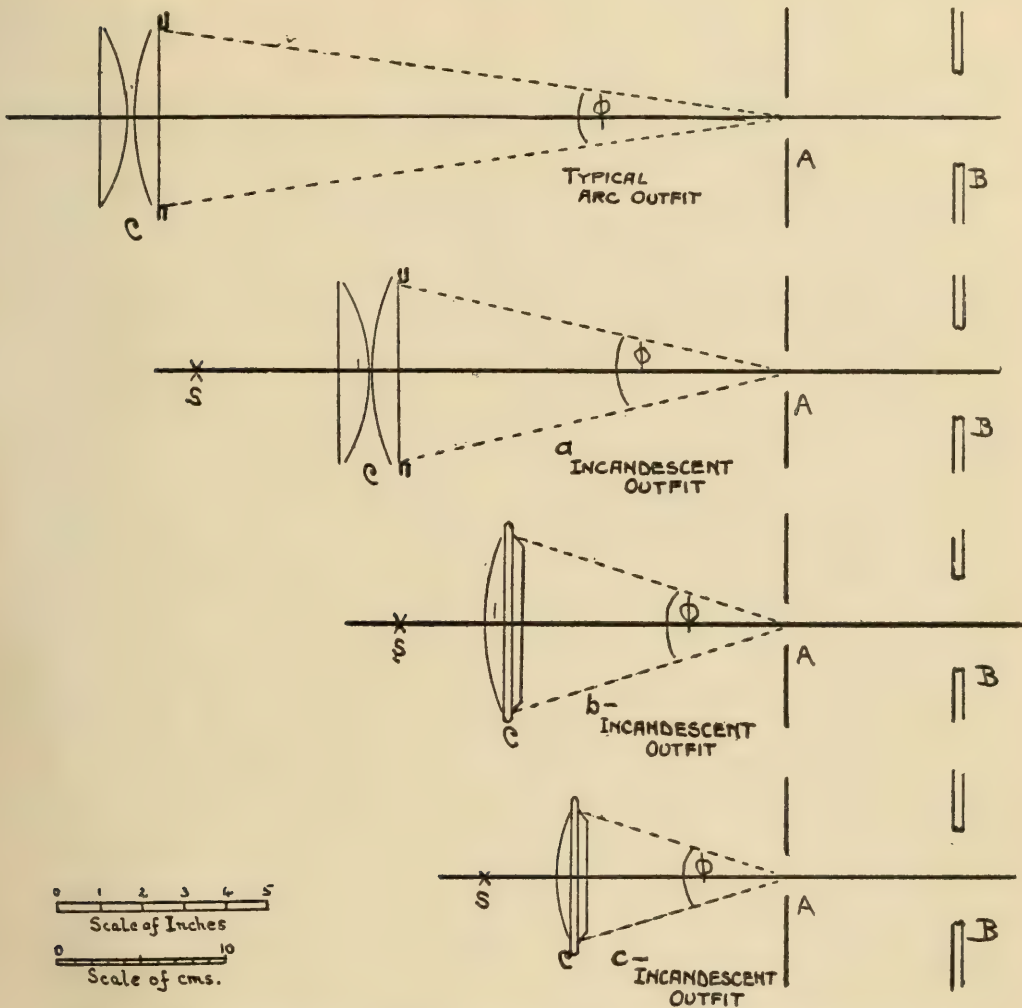


Fig. 4.—Scale drawings showing especially the angles which the condenser subtends at points on the film. *C*, condenser; *S*, center of source; *A*, "aperture plate," *i. e.*, frame of film; *B*, objective hole in machine head.

The condenser, in each of the alternative systems, subtends a much larger angle at the film than is customary in arc practice. The importance of this has already been mentioned. The diagrams here given demonstrate this. (See Fig. 4.)

Arc practice is quite variable and we have selected for comparison the layout advocated by Mr. F. H. Richardson, who has devoted much effort to improving and standardizing arc outfits.²

² Motion Picture Handbook, 1915, New York, 3rd Edition, p. 140.

We are some times asked why it is not better to vary the condenser and lamp according to the "speed" or angular aperture of the objective. The point has been considered and the decision reached that no good purpose would be served.

The Corning condenser (see Fig. 5), used in two different sizes in outfits A and B, deserves a special note.

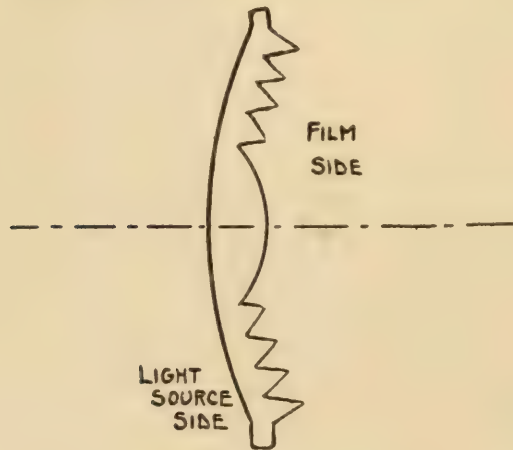


Fig. 5.—Section of the Corning condenser.

This condenser is what is known as a Fresnel lens, *i. e.*, it has prismatic rings. Such a construction has one main advantage and one main disadvantage. The advantage is that the lens is not inordinately thick and the disadvantage is that there are unavoidable discontinuities between the rings which result in some loss of "aperture" in the condenser. Incidentally, we may mention that the fact that the lens is a moulded product renders it easy to obtain forms of surface which are better suited to the present purpose than would be regular spherical surfaces. The glass used is a heat-resisting variety.

PROVISION IN VIEW OF LAMP FAILURE.

It is essential in theatre work that interruption of performance be avoided just as far as is possible. This means provision for very rapid substitution of a new lamp in place of a burnt-out one. The problem has been solved in two or three ways, and the solutions are entirely practicable. Description of the mechanism used for this purpose and also for the adjustment of lamp and mirror would be out of place here. (Fig. 6.)

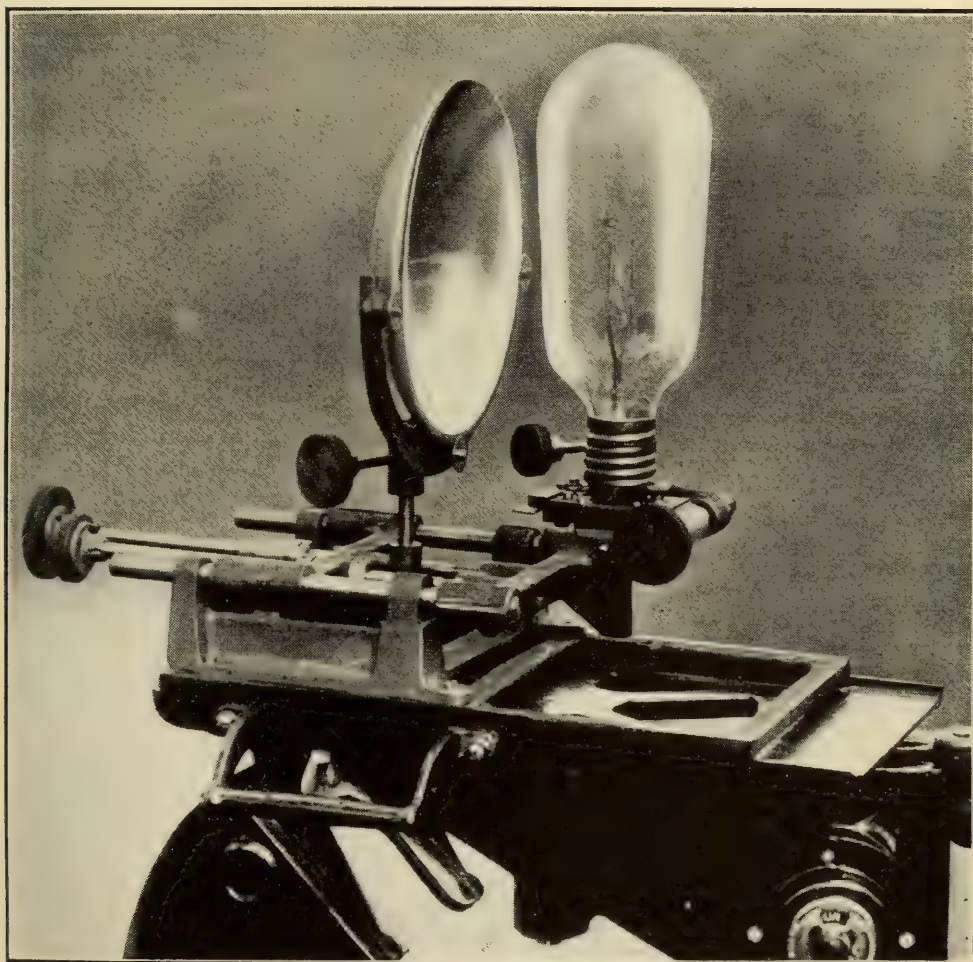


Fig. 6.—Lamp and reflector adjusting mechanism.

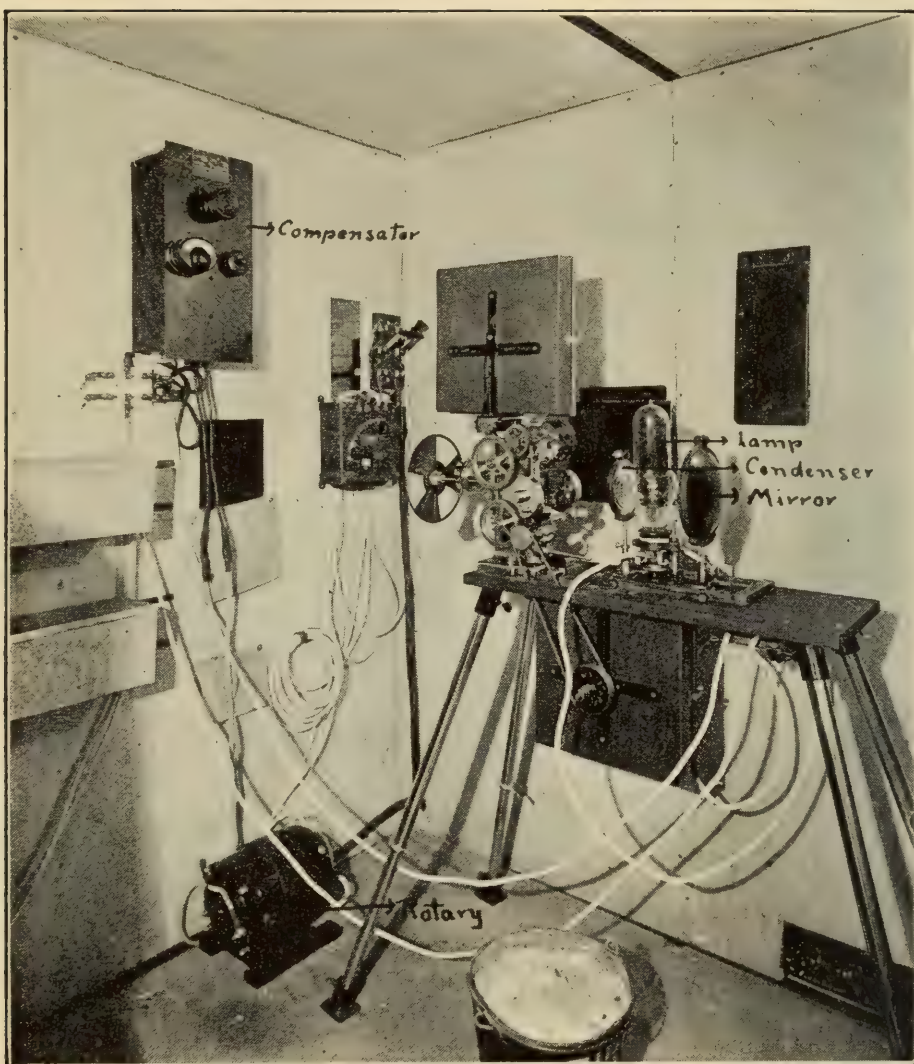


Fig. 7.—Experimental set-up of incandescent lamp motion picture equipment.

Suffice it to say that the adjustment of the spare lamp is accomplished before hand, as occasion serves, and when the lamp has to be brought into action simple mechanical interchange is all that is necessary.

PROJECTION LENSES.

In general, good results are obtained with the incandescent lamp and the existing projection lenses. However, it should be explained that of the two common sizes of objectives used in theatres, $1\frac{3}{4}$ in. and $2\frac{1}{2}$ in., (4.5 and 6.4 cm.) the larger are capable of about twice as much screen illumination as the smaller *when the incandescent outfit is used*. With the customary arc outfits, full advantage of the working opening of the $2\frac{1}{2}$ in. (6.4 cm.) objective is not taken. This does not mean that some part of the opening is unused, but that any one point on the screen is served by a limited part of the lens opening. With the incandescent arrangements the larger objectives—costing only a few dollars more than the others—are very desirable.

In the longer focal lengths which are used in exceptionally large theatres it would be sound engineering to go to even larger diameter lenses. We have had such lenses made but the present arrangement of the machine head has to be modified before they can be used to advantage. However, the increased cost of such a modified outfit, including extra large lenses, would be trivial compared with other items involved in theatre work of that class, and this may prove an interesting future development.

THE SHUTTER.

The shutter of projection machines would be good subject matter for a separate paper. We will open our very brief account with the note that the results discussed in this paper can be obtained with the existing shutter arrangements. Our purpose is to indicate how the very best results can be obtained and how one can make advantageous changes in the future.

The separate pictures on the film succeed each other at the rate of 16 per second, and the primary function of the shutter is to intervene during those intervals in which the pictures are jerked along. But since 16 flashes a second gives intolerable flicker, the shutter has the secondary function of intervening

either once or twice during each interval in which the film is stationary; so we have the 2- and 3-wing shutters, making respectively 32 and 48 flashes per second. Flicker depends not only on the frequency of the flashes but also on the brightness of the picture viewed; 48 flashes per second is almost beyond reproach while under certain screen conditions 32 per second is dangerously low.

The choice of shutter is based on the following considerations:

(1) With light sources which do not pulsate in intensity (*e. g.* the tungsten lamp and the d-c. arc) either shutter may be used; flicker is more apt to occur with the 2-wing but the efficiency of light transmission is rather better than with the 3-wing. Standard practice is to use the 3-wing, however.

(2) With pulsating light sources (*e. g.* the a-c. arc) there is a possibility of a bad, stroboscopic flicker of very low frequency if certain relations exist between the shutter characteristic and the a-c. frequency. The customary 60-cycle service and the 3-wing shutter constitute the commonest example. Hence, standard practice with a-c. arcs is to use the 2-wing; since the 32 flicker of the shutter is less objectionable than the 12 flicker of the stroboscopic effect.

Whichever shutter is used there is always a substantial reduction in illumination produced. One vane of the shutter must be gauged so as to correspond with the interval in which the film is moving. Obviously the root cause of loss of light on this account is the mechanical limitation of the intermittent device.

The other vane or vanes of the shutter are usually made rather smaller than the first, apparently on the principle of accepting a little flicker for the sake of obtaining a little more light. The practice seems questionable.

Apart from all this, however, there is an important relation between the diameter of the shutter and the cross-section of the light beam in which it operates. Since the shutter axis is fixed on existing machines it is hardly practicable to take account of this.

In future developments, attention to shutter geometry is likely to improve projection all around, especially, where large aperture objectives are used. In closing this subject we would point out

that the incandescent system gives a "projection beam" which diverges from the objective outwards. Hence, the best shutter plane is one close to the objective.

The existing arc systems almost invariably give a beam which converges between the objective and a plane several inches ahead, after which it diverges again. This "stopping-action" of the image of the condenser opening has already been referred to, and it calls for a shutter plane further out from the machine.

THE ADVANTAGES AND DISADVANTAGES OF THE THREE SYSTEMS COMPARED.
(Arbitrary Order.)

Feature	A	B	C
Applicability to existing machines (See Note a)	A small housing to be attached to the front of the existing housing or an entirely new housing may be used		The existing housing of one make of arc outfit can be used
Projection of lantern slides (See Note b)	Both the corning and plano-convex condenser lenses are carried on the one housing, the plano-convex serving for the slides		One condenser system is used for both film and slide projection
Power consumption. (See Note c)	600 watts	750 watts	1,200 watts
Evenness of illumination	Excellent	Excellent	Good (See Note d)
Lamp cost* (N.B., all have same expectation of life)	\$6.00	\$6.75	\$9.00
Clearance between condenser and film (See Note e)	5 in. (12.8 cm.)	6½ in. (16.5 cm.)	9¼ in. (24.2 cm.)
Intensity of screen illumination	The intensities of illumination obtainable with any of the three systems are of the same order of magnitude		

* These are typical present list prices.

In fairness to each of the systems, a few notes are added for the benefit of those who are unfamiliar with movie theatre work.

- (a) The life of movie machines is comparatively short so that to replace a housing is not anticipating the scrapping of the old one by more than a few years, on the average.
- (b) The separate lantern for slides is not uncommon even in theatres where arcs are used. A slide objective is needed whether a combined film and slide machine is used or separate machines, and there is something to be said in favor of independent apparatus. The lamp required for *separate* slide projection may be a common stereopticon lamp and it can run direct on the supply voltage.

- (c) The screen illumination is not directly related to the watts, as there are other factors entering in.
- (d) The degree of unevenness of screen illumination implied is noticeable when there is no film in the machine, but not otherwise.
- (e) The significance of "film to condenser" clearance is this: Some operators find it convenient to have a large clearance when they are threading film, "framing-up" or doing other work on the "machine head." This seems to depend greatly on the individual operator.

CONTROL APPARATUS.

The requirements to be met by the control apparatus are these:

- (1) Provision is to be made for operating the lamp (which is essentially a low voltage type) from the customary lighting or power circuits.
- (2) Means for enabling the device to operate on different supply voltages of the 110- or 220-volt range.
- (3) To secure relative uniformity of results in regard to illumination and life of lamp, some indicator of current strength is a very desirable feature, and with this naturally goes.
- (4) A means of adjusting the current.
- (5) In order to avoid occasional trouble from weak spots which are apt to exist in the best apparatus, it is desirable that means be provided to ensure a somewhat less violent onset of the current through the lamp than occurs with a mere single-throw switch direct connected. (The resistance of the lamp filament when cold is little over one-twentieth of the resistance under operating conditions.)

For a-c. service there are several controllers on the market which are designed to meet these conditions. All of them are in the form of compact metal wall cabinets, but the provision for the various requirements differs somewhat, as shown in the following table:

METHODS BY WHICH THREE TYPICAL CONTROLLERS MEET THE REQUIREMENTS.

	X	Y	Z
(1) Conversion of current received from supply lines	Auto transformer	Auto transformer	Auto transformer
(2) Provision for different line voltages	Transformer tap served by switch	Adjustable magnetic shunt	Adjustable reactance in primary circuit
(3) Current indicator	Ammeter	Ammeter	Ammeter
(4) Means for current adjustment	Rheostat in series with primary	Adjustable magnetic shunt	Adjustable reactance in primary circuit
(5) Suitable starter	Three-way switch and resistance in primary	Three-way switch and resistance in primary	The one-way switch is accessible only when the adjustable reactance is "all in"

On d-c. service not corresponding to the lamp voltage it is necessary to use a rotary machine of some kind, unless one prefers to waste power in rheostats or has available a suitable battery with series-parallel connections. Alternating current is so generally available in this country that but little attention has been given to the direct-current alternative.

(Both a-c. and d-c. equipment are shown in Fig. 7.)

Where central station service is not available it is possible to use any one of a number of small low voltage generating outfits.

ADVANTAGES OF THE INCANDESCENT LAMP OVER THE ARC LAMP.

We have already indicated that most of the present arc outfits can be replaced by incandescent lamp outfits without loss of illumination, in fact there is often a gain.

Leaving aside the illumination then, what advantages can the incandescent lamp show?

In our opinion the following advantages can be claimed. (The order is arbitrary.)

Where the a-c. arc is replaced, vastly more uniform screen results are obtained, noise is eliminated and continuous fussing with the light source is avoided.

Where the d-c. arc served by rectified or converted current is replaced there is a considerable gain in uniformity of screen results, the frequent "feeding" is avoided and the auxiliary apparatus is more simple and durable.

Whatever the style of arc replaced there are further advantages in the markedly reduced running expenses and lower first cost: freedom from cracked condenser trouble, fumes, and the intensely hard dust which comes from electrode cores (and causes film-scratching, excessive machine wear and unsanitary conditions).

The color of the light is more nearly what is demanded to-day; the difficulties of the operator are greatly lessened, and the booth is much cooler.

Since the starting of the lamp is well-nigh instantaneous there is no warming-up process incidental to the "change-over" at the end of each reel; thus no overload capacity is required in any of the electrical equipment.

Unsteadiness and flicker are foreign to the incandescent system since with this system they can only occur with improper shutter provision or adjustment. Similarly, the frequency of alternating-current supply is of no significance once the right controller for that particular frequency has been installed. This is especially important in the big 25-cycle territories. We would especially emphasize the fact that *the only adjustments of the light-source and related parts are made when a new lamp is screwed into the machine.* True, an occasional glance at the ammeter and a touch of the regulator handle are advisable, but this is very simple, and may be done as opportunity occurs.

At first sight there is an apparent disadvantage in the fact that the failure of the lamp may occur during a performance. But with the duplicate lamp arrangements which are provided, a lamp replacement causes no more interruption than the restriking of an extinguished arc and far less than a replacement of carbons.

In fairness it must be said, however, that a number of the advantages are dependent on the availability of a-c. supply. While the case is still very strong where alternating current and direct current are available, we must admit that where direct current is the only service available, the question is yet to be determined.

Outside of the real movie-theatre field there are a great many situations where the supply wiring would not be equal to the demands of the wasteful arc outfits, but would safely handle the current needed by the incandescent system.

APPENDIX.

Screens and Films.

Screens used in practice vary in reflecting power through a considerable range, but after all, reflecting power (the total amount of light returned by the screen when subject to a known degree of illumination) is not a very direct gauge of performance. Of the total solid angle within which the redirected light may emerge there is only about one-fifth which is usable *i. e.* suitable for placing spectators in, irrespective of the arrangement of the auditorium.

In many theatres the useful angle is restricted vastly within this value by the general seating arrangements or shape of building. The significant factor in regard to screens is evidently the

brightness as viewed in various directions, standard illumination being assumed. Fig. 8 gives some typical data from which it may be seen that a proper choice of screen is very important, and that the illumination determines only relatively the brightness of the picture. It is important to notice that a very slight accumulation of dust can reduce the screen brightness very materially. With a schedule of regular and frequent cleaning, theatre managements can in many cases increase their picture brightness by fully 50 per cent. of their average value.

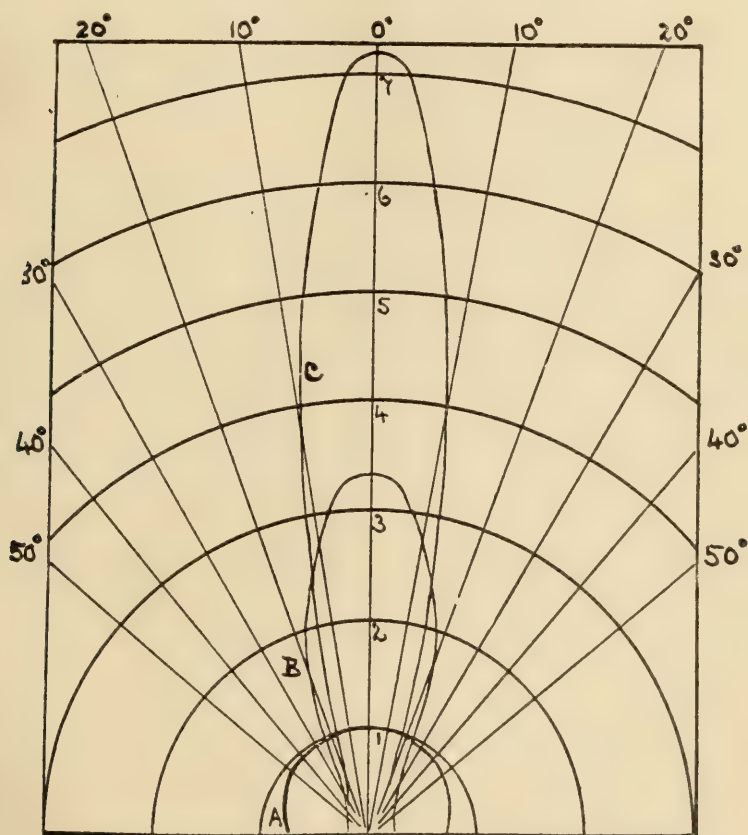


Fig. 8.—Brightness of the three screens under the same illumination (after Gage).
A, magnesium oxide; B, aluminum bronze; C, mirror screen.

Another matter which has a secondary bearing on our subject is the lack of standardization of film densities. Illumination difficulties will be very largely reduced when film producers put an end to the chaos which exists in this respect. We are glad to notice that efforts are already being made.

General Illumination of Theatres.

There are more considerations that come under this head than at first sight appear.

The effect of extraneous illumination falling on the screen is to decrease the contrast between the high lights and low lights of the picture. If for example, the intensity of the beam in a low light of the picture is $1/50$ footcandle and in high lights, say 2 footcandles, the contrast is 1:100. If upon the screen image is now superimposed an intensity of $1/10$ footcandle due to extraneous light, the contrast becomes approximately 1:17.

At the same time it is much less trying to the eyes if the *surroundings* of the screen in the field of vision are reasonably bright, although it is very undesirable to have the uneven brightness which is so generally seen at present.

A further point relates to color. It seems highly probable that the present tendency to resort to various means of producing a yellowish tint in the screen picture is due to the disagreeable color contrast between the general illumination and the projection illumination. While the tungsten projection lamp is somewhat better in this respect than the arc, it is likely that tinted films and tinted screens—both light wasters—will continue to be used as long as the general illumination is produced from yellow, dimmed lamps.

We are now investigating means of illuminating the theatre in accordance with these principles.

The Commercial Field.

Since April 1915, when we became actively engaged in the study of light projection with tungsten lamps, we have made and are keeping up-to-date a complete investigation of the field which can be served with an incandescent lamp of this character. This investigation shows that in the United States at the present time there are approximately 22,000 theatres besides colleges, hospitals, laboratories, churches, lodge rooms, schools, museums, state institutions, and similar places which collectively would use between 30,000 and 40,000 projection machines. The field is further increased by the development of country home lighting and other isolated plants which serve communities that do not have central station service at the present time. Fifty per cent.

of the theatres throughout the country operate on a simple alternating-current basis; 30 per cent. operate through rectifiers or a-c.—d-c. converters, and the remaining 20 per cent. operate directly from direct-current circuits.

FIELD FOR INCANDESCENT LAMPS FOR MOTION PICTURE PROJECTION.

Seating capacity	250	251-500	501-800	800 or over	Total
Number theatres in U. S.	9,159	7,214	2,533	2,219	21,155
Per cent. of total	43.3	34.2	11.9	10.4	100

Of the total number of theatres (21,155) approximately 80 per cent. can use incandescent lamps as light-source for their projectors.

Theatre-Installations.

Our first installation of the tungsten lamp for motion picture projection was made in the Virginia Theatre at Cleveland, on June 1, 1915. This was purely an experimental installation. The first public installation in a theatre was made on October 24, 1915, in the Home Theatre of Cleveland, which has a seating capacity of 675 people. The projection apparatus in the theatre has a throw of 58 ft. and gives a picture 13½ ft. wide on a white painted canvas screen. The general illumination in the theatre is unusually high. In service for 25 months, the installation is still working satisfactorily to the manager, operator and patrons.

A later installation was made in the Windermere Theatre in East Cleveland, Ohio, June 25, 1916. The throw is 131 ft. (40 m.) and the picture is 16½ ft. (5.1 m.) in width on a *radium gold fiber* screen. The seating capacity of the theatre is 1,000. The arc equipment replaced operated at 65 amperes direct current, and for one and one-half years the performances have depended on incandescent lamps entirely. We should say, however, that the outfit differs somewhat from those illustrated in this paper; it was arranged in accordance with our intention of developing an outfit to take care of the longest throws and largest sized pictures. This is still in the experimental stage.

FUEL CONSERVATION POSSIBLE IF ALL PROJECTION ARCS IN MOVIE THEATRES
WERE REPLACED BY INCANDESCENT LAMPS.

Average run of 45 hours per week or 2,340 hours per year.	
Number of theatres in the United States, 22,000.	
Total theatre-hours per year, 51,000,000.	Watts
Average overall wattage with arc systems	3,000
Average overall wattage with incandescent systems	900*
Difference	2,100

Assuming three pounds of coal consumed per K.W. hour at the theatres, this means a saving of:—

$51,000,000 \times 2.1 \times 3$ lbs. of coal per year,
or 160,000 tons,
or 4,000 cars of 40 tons each.

DISCUSSION.

A. S. CORY (communicated): Under the sub-caption *Projection Lenses*, the following statement appears:

“This does not mean that some part of the lens opening is unused, but that *any point* on the screen is served by a limited part of the lens opening.”

This must have been overlooked by the authors in revising their paper, for, in view of Mr. Orange’s very able exposition of the “Limiting Illumination” on the projection screen, in the TRANSACTIONS of the Society for November, 1916, I really cannot believe that he means to assert what I have quoted above. It appears to me that the passage quoted should have been written as follows:

....*certain* parts of the screen, *i. e.*, the edges of the picture, are served by only a limited portion of the lens opening.

I am also aware that all of the authors of the paper are of the opinion that the use of projection objectives of large effective aperture is a step in the right direction, but from the standpoint of practical optics, and from considerations relating to the best screen interpretation of the photographic values of the pictures on the film, it can readily be shown that, in the case of projection lenses of less than 6 in. *e. f.*, increase in aperture, in addition to being attended by falling off in definition, also affects the proper

* 900 watts is arbitrarily taken from the average wattage of the three lamps described in this paper (600, 750 and 1200 watt types) together with an allowance for loss in control apparatus.

photographic contrasts of the screen picture detrimentally. As this subject of increased lens aperture applies in the same manner to projection with the carbon arc as to the tungsten-filament lamp, I propose to treat this in due course in the journal with which I am connected, and so will not expatiate at length upon it at this time. I would like to state it as my opinion, however, that for practical mechanical reasons—and we must always keep the practical end in mind—also for optical considerations, the nature of which has been suggested above, the tungsten—filament projection lamps must be so designed that they are independent of the use extra large aperture projection lenses, before they may be considered eminently suitable for the highest standard of motion picture reproduction.

J. A. ORANGE: With regard to Mr. Cory's first point, *viz*: as to the amount of objective opening serving various parts of the screen, the following remarks apply. The statement quoted is quite correct as it stands and the qualification suggested by Mr. Cory ("*certain* parts of the screen") is therefore unacceptable.

In explanation of our statement we can offer a simple geometrical argument and a practical test of the easiest and most direct kind.

A $2\frac{1}{2}$ in. (6.3 cm.) objective when used in arc projection of the orthodox kind is almost always followed by an image of the condenser opening some 1 to 2 in. (2.5 to 5.1 cm.) in diameter and situated some few inches from the front of the objective.¹ Since all of the light used passes through this small circular image or "window" and since in air, light travels in straight lines, it follows that *any* point on the screen will be served by an area of objective opening which is only very slightly larger than the "window." Anyone doubting this can lay out a drawing comprising, say, an objective front $2\frac{1}{2}$ in. (5.3 cm.) in diameter, a "window" $1\frac{1}{2}$ in. (3.8 cm.) in diameter situated 4 in. (10.1 cm.) from the objective, and a screen 70 ft. (21.4 m.) distant. From any point whatever on the screen it is at once possible to draw lines which will show how much of the objective opening is used by that point.

It is true that in a few cases the image of the condenser open-

¹ TRANS., I. E. S., Vol. 11, No. 8 (1916), pp. 780-782.

ing (here called the "window") may be as large as the objective opening or even larger. In such cases it is correct to say that the central parts of screen are served by all of the objective opening, while the edge of the screen is served (usually) by a restricted portion of the opening.

Finally, we believe the following direct test is unanswerable. With the fire door propped open and no film in the machine hold a piece of thin metal pierced with a needle-hole against the film gate. A piece of paper held against the front of the objective will show conclusively which part of the objective opening serves that point on the screen at which the needle hole is projected.

With regard to Mr. Cory's second point, *viz.*: the use of large aperture objectives, it is not necessary to add much to our answer to Mr. Richardson's discussion.

The focal lengths of the objectives used in theatres are pretty well confined to the 4 in. to 8 in. (10.1 to 20.2 cm.) range. From 5½ in. (14 cm.) downwards there have been commercially available for years lenses of speed about $F/2.2$ —*i. e.*, a diameter of 2½ in. (6.3 cm.) at 5½ in. (14 cm.) focal length and proportionately in other cases.

In this range of focal lengths [5½ in. (14 cm.) downwards] we advocate the use of these high speed yet thoroughly commercial lenses, rather than the hopelessly low speed lenses which are all too commonly used.

The range of focal lengths from 5½ in. (14 cm.) upwards is at present served commercially by lenses 2½ in. (6.3 cm.) diameter and by certain smaller diameters. The wisdom of using the former—the 2½ in. (6.3 cm.) diameter—where these focal lengths are called for can well be insisted upon, and we point out *as an interesting future development* the possibility of making the longer focal-length lenses in as high "speeds" as the present 5½ in. (14 cm.) focus lenses, that is by making the lens diameter proportional to the focal length throughout the series.

F. H. RICHARDSON: With regard to the 4 in. (10 cm.) diameter objective, I believe its use would entail serious loss of definition. In the second place, what kind of a revolving shutter would its use call for on the present machines? Even now, to get good conditions with the arc, under certain circumstances, we must place the revolving shutter 15 in. (38 cm.) from the lens

in order to get the best results. With the 4 in. (10 cm.) lens, I do not believe you could get any kind of a result at all, with present machines and the present type of revolving shutter.

I don't want to discuss this matter here, except to call attention to the fact that, while in theory you might add illumination with increased speed of objective, practically I don't think you can do it. I will say that I was much pleased with the demonstrations here to-night, but I believe that Mr. Orange's remarks in regard to the theatre conditions and his application to the new form of illuminant simply proves out my own contention in this matter, and that is that this illuminant at the present time may equal, we will say just for the sake of giving figures, a 40 or 50 ampere alternating current-arc, 60-cycle; it will improve the conditions. with any 25-cycle current; it may equal a 20 or 25 ampere direct-current arc. That is a fair basis to work on, because if an arc of given amperage will produce a given result under a given theatre condition, then by placing this lamp under the same condition we are making a workable comparison. I believe that we should put the thing on a basis that is right and fair; and I hold that that is a fair basis for comparison of the high efficiency incandescent lamp and the arc can only rest upon amperage of the arc and actual theatre conditions. To my mind there is no question but what this new lamp has a legitimate field; there is no question but what it will improve the results in many theatres, but I do question the proposition that it can fill nearly the entire field. I think that is impossible at this time. The increasing of the illumination by means of increased lens speed, I think is an impractical proposition, unless you build some new form of projecting machine revolving shutter.

J. A. ORANGE: Mr. Richardson takes exception to the mention that I made of the 4 in. (10.1 cm.) diameter objective. You will notice in the printed copies of the paper, that no claim is made for the ready use of an objective of that kind, but before an engineering society of this kind and standing, I think that it is entirely proper to refer to the developments which are in sight, the things which can be taken up, and not just the things which are being handled at the present time.

If I led anyone to suppose that a 4 in. (10.1 cm.) diameter objective was a thing that anyone of us would now be prepared to

offer to the large theatres, I would wish to correct myself immediately. My point is this: That the cases where, without making difficult changes in the apparatus, one can replace the arc—those cases constitute about 80 per cent. of the theatres now existing. I don't think we need go into that question. Mr. Richardson practically acknowledged it in his discussion.

It is interesting, I think, to an engineering society, to know what the difficulties are in the way of serving the whole field, what would have to be done to use the very convenient incandescent lamp in the extreme cases. I think I pointed out before, that those extreme cases are the cases where expense is really no object; that is, if a \$50.00 increase in a lens, or if a change in the machine head, (a reasonable mechanical change), will give the results, then the management of such theatres will be ready to consider it.

I have no actual experience with a 4 in. (10.1 cm.) diameter objective. I have some experience with a 3 in. (7.6 cm.) and I think that all those present who are interested in the optical question, that is, in the strict sense, the question of projecting pictures with good definition, will agree that the difficulty of getting definition turns on the speed and not on the absolute diameter of the lens. If I understand Mr. Richardson right, he means to assert that while one can take a $5\frac{1}{2}$ in. (14 cm.) focal length objective of $2\frac{1}{2}$ in. (6.3 cm.) diameter, and get good pictures, you can't scale the thing up in focal length and diameter to handle the longer throw. I leave that matter to the people who are interested in geometrical optics. I don't think I need to discuss it.

The question of the difficulty of using shutters with large diameter objective, is a very real one. That is mentioned in the text of the paper, but I think it will be conceded that the present shutter is a very simple, not to say crude, device, and that in the only cases where anyone would think of going to the most extreme development, which is a 4 in. (10.1 cm.) diameter lens, the possibility of changing the shutter would be one that we could get consideration for. The question of changing these shutters is one that has been discussed for some years, and there are various ways, without going to great elaboration, in which

the shutter difficulty that Mr. Richardson speaks of can be avoided.

He says that in some cases at present it is necessary to go a great distance from the objective to place the shutter. It seems to me there is a very involved matter here. The size of shutters and the design of shutters is tied up very largely with the size of the light-beam in which they operate, and it is true, that with your existing machines, the beam coming from the machine has its smallest section some distance from the objective. In fact, that very smallness is the reason for the poorness of the optical layout at present, but it is the fact that there is such a small place in the beam which enables you to use a crude and simple shutter.

All I will say is, that for the things that we are seriously considering at the present time, not the developments that we are hoping for; that is, confining ourselves to the $2\frac{1}{2}$ in. (6.3 cm.) diameter objectives, there is no real difficulty in using the existing shutter mechanism and placing it as near as possible to the objective; and I say that for these objectives, that all opticians admit it is possible to devise shutters which will be relatively simple mechanical contrivances.

In conclusion, the paper states specifically, that the claims made are limited to some 80 per cent. of the theatres, that is, as to what can be offered with existing lenses and appliances which are being sold now by the hundreds, if not by the thousands. The question of the other 20 per cent. is just an interesting engineering proposition.

At another place in the paper the question of operating on direct current circuits is also taken up, and I think it is there stated specifically that where direct current only is available, the question of incandescent lamps has not yet been thrashed out. That is largely a question of the auxiliary apparatus. It is necessary to use something more expensive in that case than in the case of alternating current circuits, and the cases where direct current is the only supply are relatively so few that we have not as yet thought it necessary to go into the matter.

F. H. RICHARDSON: If I conveyed the impression that the incandescent lamp had not made out a case, I failed to make myself misunderstood. I meant nothing of that sort. I believe I said I

was agreeably surprised by the result shown here to-night. What I tried to say was, that the incandescent lamp unquestionably has its field, but I also intended to convey the idea that there had been some claims made, not in this paper, for the incandescent lamp which I believed could not be substantiated. That was all. I would like, if you don't mind, to ask you a question just simply for information. I have been somewhat puzzled with this: The globe of the incandescent lamp, it seems to me, may be regarded as a lens, regardless of its thinness. Is there really any such action?

J. A. ORANGE: It can be regarded as a lens in the same sense that a window-pane can be regarded as a lens. The thickness of the glass is the same, or within a few mils of being the same all around. The lens action is entirely negligible.

F. H. RICHARDSON: I haven't studied that out, but it struck me as an interesting point, and I wanted to ask you.

One other question: I wanted to ask you with regard to the use of a mirror. You admitted it would cause reheating of the filament; can this reheating be controlled when a mirror is used? In other words, what I am getting at is, there seems to be quite a failure of lamps, due to fluctuation of voltage for one thing. This fluctuation is now being controlled by new devices, so that danger to this filament is being decreased. But there still is a reheating of the filament. That is acknowledged by all who have studied the question. Can the temperature of the filament be controlled where a mirror is used? I have heard the statement that there are difficulties there. Is that true?

J. A. ORANGE: I have not heard of any difficulties of that kind. That is, the projection of a filament image by the mirror back on to the filament, or on to the interspaces, is so uniform that any question of "spotting"—I think that is what Mr. Richardson means—any question of local over-heating at some part of the filament giving trouble, is avoided. I don't think anything of that kind has been found.

With regard to the alignment and the heat of the arc as compared with that of the incandescent lamp; the different mechanisms used differ somewhat in the details, but the filament must be properly aligned with the mirror, and the two together properly

aligned with the condenser. One particular case is selected and illustrated in the paper with one particular make of machine, one type of mechanism, not with the idea that that is in any way better than the others of course.

The focusing of the filament with the mirror and with the condenser is something which is taken care of by the preparation of the lamps beforehand for the emergency when they have to be made use of; that is, when one inevitably burns out and a new lamp has to be substituted. The spare lamp with its holder is then in a condition to go into place by simple mechanical substitution. Adjustment is, of course, necessary (and careful adjustment) in the preliminary preparation.

As to the question of the heat, if it relates to the heating of the film, I don't think any measurements have been made. The difference in the degree of heating of the film for a given amount of light utilized, as between the common arcs and the lamp, is probably slight. It might even be worse for the incandescent lamp than for the arc. I am not making any claims that the incandescent lamp is cooler (for the film) than the arc is, but whatever illuminant is used for moving pictures, the heat will always be such that the film will fire if any opportunity is allowed for it to stand still. Small, portable machines, of course, don't come under this discussion.

CODE OF LIGHTING
Revised Rules of the Code of Lighting Factories, Mills
and Other Work Places.

RULES.*

Rule 1. General Requirement.—Working or traversed spaces in buildings or grounds shall be supplied during the time of use with artificial light in accordance with the following rules when natural light is less than the intensities specified in Rule 2.

Rule 2. Intensity Required.—The desirable illumination to be provided and the minimum to be maintained are given in the following table :

	Foot-candles ¹ at the work	
	Ordinary practice	Minimum
(a) Roadways and yard thoroughfares...	0.05- 0.25	0.02
(b) Storage spaces	0.50- 1.00	0.25
(c) Stairways, passageways, aisles.....	0.75- 2.00	0.25
(d) Rough manufacturing such as rough machining, rough assembling, rough bench work	2.00- 4.00	1.25
(e) Rough manufacturing involving closer discrimination of detail.....	3.00- 6.00	2.00
(f) Fine manufacturing such as fine lathe work, pattern and tool making, light colored textiles	4.00- 8.00	3.00
(g) Special cases of fine work, such as watch making, engraving, drafting, dark colored textiles	10.00-15.00	5.00
(h) Office work such as accounting, type-writing, etc.	4.00- 8.00	3.00

NOTE.—Measurements of illumination are to be made at the work with a properly standardized portable photometer.

*These revised rules were adopted on June 26, 1917. The original Code of Lighting Factories, Mills and Other Places was first published in the TRANSACTIONS, Vol. X, No. 8, p. 605, November 20, 1915.

¹The foot-candle, the common unit of illumination, is the lighting effect produced upon an object by a standard candle at a distance of 1 foot; at 2 feet, the effect would be not ½ foot-candle, but ¼ foot-candle, etc. A lamp which would give off 16 candlepower uniformly in all directions would produce a uniform illumination of 1 foot-candle at a distance of 4 feet in any direction.

Rule 3. Shading of Lamps.—Lamps shall be suitably shaded to minimize glare.

NOTE.—Glare, either from lamps or from unduly bright reflecting surfaces, produces eye-strain and increases accident hazard.

Rule 4. Distribution of Light on Work.—Lamps shall be so installed in regard to height, spacing, reflectors or other accessories as to secure a good distribution of light on the work, avoiding objectionable shadows and sharp contrasts of intensity.

Rule 5. Emergency Lighting.—Emergency lamps shall be provided in all work space aisles, stairways, passageways, and exits to provide for reliable operation when, through accident or other cause, the regular lighting is extinguished. Such lamps shall be in operation concurrently with the regular lighting and independent thereof.

Rule 6. Switching and Controlling Apparatus.—Switching or controlling apparatus shall be so placed that at least pilot or night lights may be turned on at the main points of entrance.

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TRANSACTIONS OF THE Illuminating Engineering Society PART II -- PAPERS

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No. 5

REPORT OF THE 1916-17 COMMITTEE ON AUTOMOBILE HEADLAMPS.*

Synopsis: I. INTRODUCTION—Instructions to the Committee and plan of report. General outline of the headlighting problem. II. THE REQUIREMENTS OF VISION—Road illumination: Intensity, distribution, direction. Visual sensitometric data: Threshold, discrimination, glare. Glare: Central spot, oblique, momentary and veiling glare. Adaptation, ideal lighting and limits of tolerance. III. THE OPTICAL PRINCIPLES OF HEADLIGHTING—Optical elements of lamp and beam. Specification and calculation of beam illumination. The modified beam. Brightness and glare. Out-of-beam illumination. IV. PRACTICAL HEADLIGHTING—Road conditions: Curving and uneven roads, crossings, approaching vehicles and pedestrians, sign boards, road margins, foliage, street lights, dust, fog, rain and snow. Dimming and tilting headlamps. Special mirrors and caps. Special front glasses. V. SAFETY LIMITATIONS—Discretion of driver. The headlight beam. Oblique reflected light. Minimum illumination, minimum spread, colored lights.

I. INTRODUCTION.

At the organization of this Committee, the chairman was instructed by the President of the Society by the direction of the Executive Council, to elucidate and summarize such scientific and technical data on the subject as would be likely to be of service to other committees in drawing specifications or in drafting legislation. The nature of the matter available and the uses to which it was to be put were such that the Committee found it advisable to prepare data for two different objectives: (1) the designing of headlighting systems and (2) the framing of legislation to

* A report presented to the Council of the Illuminating Engineering Society by the 1916-1917 Committee on Automobile Headlamps.

regulate headlighting. This Committee has left to other committees the reduction of the principles of headlighting to details of practice or to the form of legislative enactments.

Since headlighting requirements must be based on the properties of the human retina in reacting to light, this report gives in Section II on The Requirements of Vision a summary of what is known of the essential, desirable and tolerable in the intensity, direction and color of the illumination provided by headlamps. The technical optics of beam lighting to produce the light required for vision within certain limits of tolerance is summarized in Section III on The Optical Principles of Headlighting. The Principles of Practical Headlighting are summarized in Section IV in which various classes of controlling devices are discussed in relation to their optical properties. Legislation, however, must be based not only upon ideal lighting, but upon the limits of tolerance required by public safety. These limits are outlined and discussed in Section V on Safety Limitations.

The subject of such proper lighting and lighting legislation has received a great deal of attention in recent years. The subject of automobile headlighting is dealt with in considerable detail by W. F. Little,¹ E. J. Edwards,² J. R. Cravath,³ H. P. Gage⁴ and S. C. Rogers⁵ in recent numbers of the TRANSACTIONS of the Illuminating Engineering Society. There is considerable uncertainty and diversity of opinion in the matter of permissible limits of tolerance and the nature of the best compromise of interest between the driver of the automobile and the person approached, but there is little diversity of opinion in the matter of safety and comfort for the driver. This report represents substantial agreement among the members of the Committee on all of the reported subjects dealt with. All the Committee feel, however, that the headlighting problem is by no means completely solved and that a perfect solution involving no compromises of interest and no discomfort through the use of headlights may never be possible. A statement is even made by competent observers that present-day driving in regions where the most stringent legislation is in force is little, if any, safer or pleasanter than at times and places where no corrective devices whatever are used.

The proper road lighting for driving an automobile may be described in terms of the intensity, direction and distribution of

the illumination provided, as objective factors and upon the condition of the observer's eye as affected by brightness and contrast in the field of view and in fields just previously viewed. The safety of the drivers of passing vehicles and of pedestrians depends upon the same objective factors, but opposed in nearly every respect. The headlighting problem is therefore essentially that of securing that compromise of interests most advantageous to both driver and passer. The light must be at least adequate for safe driving without undue interference with the vision of the passing driver. Adequacy for safe driving is determined by the discriminating ability (sensibility to contrast) of the driver. Safety for others is determined by the amount of blinding effect produced. The intermediate ground of adequate lighting without interference with vision requires rather close adherence to certain specifications, but these specifications may be met without difficulty under normal road conditions.

A great deal of confusion has arisen because the requirements of safety have not been carefully distinguished from those of mere comfort or personal preference. Both must, of course, be considered, but each in its place. Considerations of pleasure or comfort, for example, have no place in framing safety legislation. On the other hand, the design of practical headlamps must not stop short with mere safety, but it is expected to provide both comfort and pleasure as well. Further confusion has arisen from the fact that personal preference depends quite largely upon the conditions and appliances to which one has been accustomed.

II. THE REQUIREMENTS OF VISION.

Road Illumination.—Safety and comfort in driving require that the intensity, distribution and direction of the road illumination lie within certain limits. These factors determine the brightness and contrast within the field of view. These, in turn, determine the sensibility of the retina; the brightness sensation, the discriminating power for slight differences in brightness and its glare sensibility or the blinding effect of a given illumination. Since the illumination affects both the visibility of object and the sensibility of the retina, it must be very carefully regulated to secure the best effects and freedom from glare. Partial lighting by street lights complicates matters and the speed of the driver involves the rate of adaptation of the retina from one intensity to another.

The *intensity* of the road illumination required is determined by the discriminating power of the retina. As is well known, the power of the eye to perceive details is very nearly independent of the field brightness at ordinary daylight brightnesses (Fechner's law). However, at low illuminations, the power of the eye to discriminate or perceive details differing only slightly in brightness becomes less and less⁶ until near the threshold of vision only rough outlines can be perceived. In the table below and in Fig. 1 are given precise data on the variation of difference sensibility or discriminating power as a function of mean brightness of field viewed, from the threshold (about 10^{-6} ml.) up to the brightness of full sunlight on a white field. At a brightness of 0.01 ml., the discrimination factor is, roughly, one-fifth of its maximum value and this brightness and discrimination (0.22 against 1.00 at the maximum) we consider most desirable for specification of road illumination by automobile headlights. It is barely sufficient for safe driving and little, if any, brighter than necessary. The discrimination is sufficient for good seeing in automobile driving where fine detail is not required to be seen. On the other hand, a much lower brightness would mean a serious falling off in power to see detail since the discrimination curve is falling steeply at this brightness.

TABLE I.—VISUAL SENSITOMETRIC DATA.⁶

Field brightness	Difference fraction	Discrimination factor	Threshold limit	Glare limit
0.000001 ml.	(1.00)	0.017	0.00000093 ml.	20.1 ml.
0.00001	(0.66)	0.026	0.0000042	40.7
0.0001	0.395	0.043	0.000019	89.0
0.001	0.204	0.078	0.000087	186.0
0.01	0.078	0.220	0.00039	400.0
0.1	0.0370	0.465	0.00174	810.0
1.0	0.0208	0.830	0.0081	1.68 l.
10.0	0.0174	0.990	0.036	3.47
100.0	0.0172	1.000	0.28	7.25
1000.0	0.0240	0.719	2.15	14.45
10000.0	(0.048)	(0.360)	(232.0)	30.90

In order that the road brightness may be 0.01 ml. if the road is illuminated at an angle of 1:30 and the mean reflecting power 20 per cent., the illumination provided must be of the order of 1 foot-candle or at 100 ft. (30.5 m.) 5,000 beam candlepower in each beam.

The sensibility of the eye varies enormously with the mean brightness of the field viewed and, to some extent, with the harshness of contrast within that field. The brightnesses met with range from 10^{-6} ml., which is barely visible to the accommodated

eye, up to 10,000 ml., the brightness of white paper in full sunlight, the brightest being 10^{10} times as bright as the faintest. In this range the sensibility of the eye varies by a factor of about 10^7 , the sensibility automatically accommodating itself to the brightness viewed. In Table I and Fig. 1 are given carefully determined data on the three chief visual sensibilities; threshold, discrimination and glare, throughout the whole range of brightness within which the eye is operative. These data are for an average normal eye. Different normal eyes will not differ greatly in sensibility under the same conditions, probably not over 20 per cent.

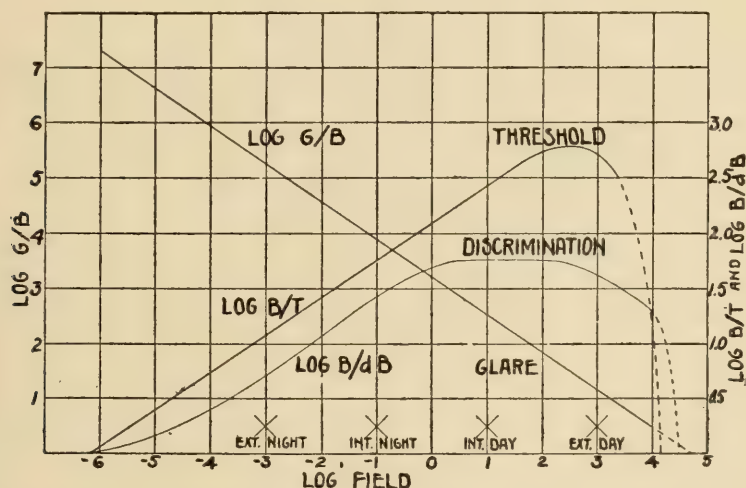


Fig. 1.—Threshold, discriminating power and glare sensibility.

In the first column of the above table are given the mean field brightnesses to which the eye is sensitized. In the second column, headed difference fraction, are given the fractions of the whole by which the brightnesses of two adjacent fields must differ in order that the difference may be just perceptible. The discrimination factor in the third column is the reciprocal of the difference fraction (reduced to maximum equal to unity) and is a quantity proportional to the power of the eye to distinguish details differing slightly in brightness. The threshold limit in the fourth column is the lowest brightness just perceptible to an eye adapted to the corresponding brightness in the first column. The glare limit in the last column is the brightness just uncomfortably bright to an eye fully adapted to the brightness of the first column. The brightness considered most suitable for road

lighting (0.01 ml.) lies midway between the brightness (0.001) which is a sort of rough average for all brightnesses out of doors at night and the average brightness (0.1) for interiors at night. For a mean brightness of field of 0.01, the least perceptible difference (from the table) is 7.8 per cent. The discrimination factor is 12.8, about one-fifth of the maximum discrimination in full daylight. The lowest perceptible brightness is 0.00039 ml. and the brightest light just comfortably tolerable is 400 ml.

In Fig. 1 are shown graphs of these data plotted as logarithmic ratios. Log *glare* sensibility is a linear function of log field brightness, such that

$$\begin{aligned}\text{Log } G &= 3.23 + 0.32 \log B \\ G &= 1,700 B^{0.32}.\end{aligned}$$

Log *threshold* sensibility is also a linear function of log field brightness except at the highest intensities.

$$\begin{aligned}\text{Log } T &= 0.66 \log B - 2.10 \\ T &= 125 B^{0.66}.\end{aligned}$$

The *discrimination factor* varies irregularly, much as it does in the case of photographic surface. It is approximately linear in the region from 10^{-4} ml. up to 1 ml. and approximately constant from 1 ml. to 1,000 ml. or 1 l.

A glaring light, *oblique glare*, at one side of the axis of vision such as might be caused by an approaching headlight, though not directly viewed, depresses sensibility. Data are not yet available for brightnesses corresponding to headlights (50-200 l.) but data obtained with a glare spot of 5 l., subtending a solid angle of about 0.0001 steradian gave data⁶ as follows:

Angle from axis (degrees)	0	10	20	30	40	No light
Relative threshold sensibility.....	0.11	0.17	0.26	0.42	0.65	1.00

For example, for the spot glare of this brightness and size at 10° from the line of sight, the eye is only 0.17 as sensitive as with the glare spot absent. The curves of Fig. 1 show that in this case any details must be fourteen times as bright to be just visible.

In headlighting, the contrast sensibility is about as important as the threshold sensibility, the depression of contrast sensibility due to angular glare, that is, the loss of power to discriminate

among details differing but slightly in brightness has not yet been determined, but a sub-committee is working upon it. The effect is known to be similar to the effect on threshold sensibility and of approximately the same order of magnitude.

Discrimination and Distance.—It is a commonly observed phenomenon that the power to discriminate details in an object like a sign board with dark surroundings increases gradually as it is approached. This phenomenon depends primarily on the variation of threshold sensibility and contrast sensibility with angular size and brightness of the light spot viewed. A laboratory investigation on the effect of size and brightness of spot on threshold sensibility has been made by Mr. Blanchard and the chairman.⁸ This data is given in the table below for the four brightnesses of test spot, 1.0 ml., 17 ml., 170 ml. and 600 ml., for six different solid angles (area divided by square of distance) ranging from the full hemisphere to 0.0001 (1 cm. square at 1 m.). With a fairly bright spot (17 ml.), threshold sensibility is independent of angular size. At higher brightnesses the sensibility increases slightly as the angular size is diminished. At low brightnesses, 1.0 ml. or less, corresponding to the brightnesses of well illuminated roadways at night, the sensibility is considerably less when the test spot covers but a small solid angle.

EFFECT OF SIZE AND BRIGHTNESS OF SPOT ON THRESHOLD SENSIBILITY.

Solid angle of bright spots	Field brightness			
	1.0 ml.	17 ml.	170 ml.	600 ml.
Full	0.0064	0.074	0.29	1.2
1.0	0.0050	0.074	0.27	1.4
0.1	0.0065	0.074	0.26	1.5
0.01	0.0090	0.074	0.22	1.5
0.001	0.0125	0.074	0.13	0.84
0.0001	0.0161	0.074	0.08	0.15

The legibility of characters on a sign board depends rather on contrast sensibility than on threshold sensibility. Data are given below on contrast sensibility recently obtained by Mr. Prentice Reeves¹⁰ (to be published shortly). His data covers six different angular sizes here given inside of square 35 cm. distant; four different times of adaptation; instantaneous, 2 seconds, 10 and 60 seconds, five contrasts; 0, 0.39, 0.67, 0.97 and several different brightnesses of background. We are chiefly concerned here

with contrast between brightnesses in the ratio of about 0.67 to 1, and initial (sensitizing) brightnesses of 0.1 ml. and less.

EFFECT OF SIZE OF BRIGHT SPOT ON CONTRAST SENSIBILITY
(MILLILAMBERTS).

3 cm. sq.	2.5 cm. sq.	1.5 cm. sq.	0.7 cm. sq.	0.3 cm. sq.	0.2 cm. sq. at 35 cm. distance
0.0038	0.0080	0.013	0.020	0.033	0.049
0.00098	0.0023	0.0050	0.002	0.008	0.035
0.00057	0.0012	0.0032	0.0078	0.013	0.026
0.00030	0.00057	0.0020	0.0054	0.011	0.020

The values given (in millilamberts) are the brightnesses of the brighter part of the field against which the contrast is just visible after the time given at the left. The sensibility is ten to sixty times as great for the 3 cm. square as for the 2 mm. square at 35 cm. distance. The largest square corresponds roughly to 10 ft. at 100, the smaller 6 ft. square 1,000 ft. distant.

Intensity of Glare Spots.—A glare spot at a fixed angle from the line of sight (30° say) may vary in brightness at constant angular area or in area with brightness constant. If the depression in visual sensibility caused by glare is measured in terms of the increase of illumination required to see with equal acuity, then log relative glare intensity is proportional to log relative illumination required, or⁹

$$\text{Log } I/I_0 = n \log G/G_0.$$

When the glare spots are street lighting units, the increased illumination required for equal seeing acuity has been found proportional to the square root of the brightness and solid angle of the glare spot, hence, to the beam candlepower. In grazing the beam from a headlight, intrinsic brightness remains constant, the solid angle (apparent size) first increases, then decreases, while the obliquity of the glare spot continually increases. The out-of-beam brightness continually increases. The glare is therefore most serious at an intermediate distance, such that the angle with the axis of vision is still small while the angular size is becoming appreciably large. This is true, roughly, in the range from 200 ft. (61 m.) down to 25 ft. (7.6 m.) in front of the approaching headlight.

Rate of Adaptation.—Both headlights and street lights passing quickly by cause a net depression of sensibility, the amount of which depends upon their brightness and rate of passing. No data are yet available on such extreme changes as those from headlight brightness to darkness, but laboratory tests have been made covering abrupt changes from a brightness of 25 ml. (roughly, that of white paper illuminated by 20 foot-candles) to complete darkness and *vice versa*.⁷

RATE OF INCREASE AND DECREASE OF THRESHOLD SENSIBILITY.

Time	$B_0 = 0, B = 25$ ml. Sensibility decrease	$B_0 = 25$ ml., $B = 0$ Sensibility increase
1 second	2.1 times	1.6 times
2 seconds	4.2 times	2.6 times
5 seconds	16.2 times	7.6 times
10 seconds	58 times	14.4 times
10 minutes	120 times	20.9 times

Since the loss of sensibility in a given interval is greater than the recovery, the net result of a succession of exposures to alternate light and darkness is, therefore, a considerable *depression* in the sensibility.

Temporary Glare.—The blinding effect of a quick flash is very much less than that caused by steady exposure to the same brightness. For an eye adapted to the darkness of night, the limit is roughly 0.2 l. when viewed directly and steadily, 0.3 l. for an object in the field but viewed obliquely (20° say), and approximately 10 or 20 l. for objects flashing by the axis of vision.¹²

Brightness Distribution for Best Seeing.—Safety in driving requires an illumination of the road from immediately in front of the vehicle to several hundred feet ahead of it, practically the full width of the roadway and with maximum brightness at a distance of 75 (23 m.) to 100 (30.5 m.) ft. (3 seconds) ahead. The illumination of foliage and other surrounding objects adds to the safety, comfort and pleasure of the driver, but it is dangerous and uncomfortable to the passer if it rises to the level of his eyes in the line of his approach. Illumination of the surroundings not only makes them visible, but increases the ability of the eye to see detail in the roadway itself by freeing the field of view from excessively harsh contrasts.⁶ The brightly illumi-

nated roadway with unilluminated surroundings gives what is merely a mild form of spot glare.

Veiling Glare.—Veiling glare is that cause of impaired vision due to a light or dark veil obscuring the field of view and of a pattern different from that of the object viewed. The veiling due to a bright glare is greater the greater the brightness of the veil relative to the field to be viewed.⁸ Such veiling is common in automobile driving due to dirt or moisture on the windshield or to fog, dust or snow between the driver and the illuminated roadway.

The effect of veiling, whether darker or brighter than the object viewed, is to suppress details by reducing contrasts in headlighting since the illumination is very nearly a minimum and therefore contrasts nearly a minimum at best. The effect of veiling is very serious indeed. A partial remedy for dark veiling is to increase the illumination of the object viewed. If light veiling, there is no remedy.

Ideal Lighting and Limits of Tolerance.—A description of what may be termed ideal lighting, so far as vision and safety are concerned, will serve as a summary of the preceding discussion of the requirements of vision. This is to be considered ideal only under ideal conditions, namely, with the automobile on a smooth road of uniform grade.

The brightness of the roadway should be a maximum (at least 0.01 ml.) over an oblong area centering, as seen by the driver, about 100 ft. (30.5 m.) ahead and nearly the width of the roadway from 50 ft. (15.3 m.) to 100 ft. (30.5 m.) ahead of the vehicle. From this area of maximum brightness, the brightness of the roadway should shade off gradually, laterally and in the extreme distance.

From the point of view of the person approached, ideal headlighting is that which produces no blinding glare in passing. This condition requires that the illuminating beam does not at any point shine in his eyes and at no point in passing the total light entering his eyes from any given direction be no more than equivalent to that from a source of, say 100 candlepower, for any length of time greater than half a second.

On lighted streets, the illumination being partly or largely transverse, larger and more contrasting shadows are present than

when the illumination is from the headlamps alone and therefore seeing conditions less suitable. Further, the net result of the alternation of lighter and darker illuminated areas is the depression of the retinal sensibility as shown above in the discussion of the adaptation effect. However, the effect of the street lights is to raise the general level of illumination and driving as a whole is probably as safe and comfortable as driving by the headlights alone.

III. THE OPTICAL PRINCIPLES OF HEADLIGHTING.

Optical Elements of Lamp and Beam.—Regarded as optical apparatus, ordinary headlamps consist essentially of three parts: (1) a concentrated source of light of moderate candlepower in or near the focus of (2) a deep parabolic mirror of $1\frac{1}{4}$ to $1\frac{3}{4}$ in. (3.18 to 4.45 cm.) focus and (3) a plate of formed glass through which the light passes, usually after reflection. If the source of light were a point and the mirror accurately paraboloidal, a beam of parallel light might be thrown on the roadway by proper focusing. Since, however, the source of light has dimensions up to as much as $\frac{1}{2}$ in. (12.7 cm.) and the mirror is of very short focus and imperfectly formed, the beam throws no true image of the filament on the roadway nor does it ordinarily form any clean cut beam.

The distance of the image formed by the central portion of the mirror may be calculated by the simple optical formula

$$1/v = 1/f - 1/u$$

or reciprocal image distance (v) equals reciprocal focal length (f) minus reciprocal distance of source from the mirror surface (u). The relative transverse dimensions of the image of the filament and the filament itself is equal to their relative distances from the surface of the mirror. For example, with the mirror of the standard focal length $1\frac{1}{4}$ in. (3.18 cm.), the image of a filament at 100 ft. (30.5 m.) is approximately 1,000 times the corresponding dimension of the filament, 20 ft. (6.1 m.) in width at 100 ft. (30.5 m.) distance corresponds to $\frac{1}{4}$ in. (6.3 mm.) in width at the focus of the mirror.

The magnification along the axis is, however, proportional to the square of the respective distances from the mirror surface, since, from the above equation, $dv/v^2 = -du/u^2$. Hence, if v is

100 ft. (30.5 m.) (approximately 1,000 times $u = 1\frac{1}{4}$ in.) (3.18 cm.) dv is approximately 10^6 times du . If the lamp filament, however, is accurately centered on the axis, the precision of focusing along the axis is of little consequence since the aim is to direct a cylindrical beam of light along the road 20 ft. wide at 100 ft. (30.5 m.). If the lamp filament is cylindrical or flares at the ends, the beam will have a decided waist at 100 ft. (30.5 m.) and flare out considerably at nearer and farther distances.

In the ideal case of a small source and a perfect mirror, the relative brightness of illuminated area of image (B_i) and source (B_o) is proportional to the solid angle subtended by the mirror and inversely proportional to the square of the magnification (m).

$$\frac{B_i}{B_o} = \frac{T\omega}{m^2}$$

where T is a constant of proportionality representing both the transmission and 1 minus the reflecting power of the mirror and ω is the solid angle in steradians subtended by the mirror seen from its focal point. In the average headlight this solid angle is of the order of 80 per cent. of the total sphere or approximately 10 steradians. The reflecting power of new nickel mirrors when freed from dust at the mean angle of incidence is about 55 per cent. If tarnished or dusty, the reflecting power is much less than this, the specular reflecting power running as low as 10 per cent. very frequently. Light scattered by dust or tarnish is, of course, as much lost to the beam as though it were absorbed, but at least half of it furnishes oblique illumination.

Specification and Calculation of Beam Illumination.—As stated above, the magnification with focus at 100 ft. (30.5 m.) is roughly 1,000 and calling the T in the above equation 0.4, B_i/B_o is equal to 4×10^{-6} . This ratio is a pure number applying, of course, only when brightness of object and image are measured in the same units; for example, in lumens per unit area per unit solid angle or in lamberts. The brightness of a lamp filament is of the order of 500 to 1,500 l.; if of 1,000 l., the brightness of a perfect image formed by a 10 steradian mirror with a reflecting power of 40 per cent. would, therefore, be 4 ml. on a surface normal to the beam. When the source of light has con-

siderable extent as in ordinary practice, the beam is formed of a complex of imperfect images, the overlapping of which gives a maximum brightness at most equal to that of a very small source of the same intrinsic brightness accurately focused.

Another method of beam calculation is to consider total flux and area. If the beam is fairly definitely limited at 100 ft. (30.5 m.), the total flux at that point is equal to that through the front of the headlamp reflected from the mirror, which in turn is equal to the total flux of the source times the fractional solid angle subtended by the mirror times the factor representing losses by transmission and reflection. For relative total flux the relation holds

$$F = \frac{F_o T \omega}{4\pi}.$$

This is perhaps the simplest method of calculation and the data may be readily converted into flux density by dividing by the area, as above, calling T 40 per cent. $\omega/4\pi$ equal to 80 per cent. Taking the flux at the source as 8 candlepower or about 100 lumens, the beam flux at a distance is 30 lumens. This is readily reduced to lumens per square foot of cross section (foot-candles) if desired and this again reduced to lumens per square foot of road surface by dividing by 30 since the angle of incidence of headlight on the road at 100 ft. (30.5 m.) is roughly 2° or $1/30$.

The Modified Beam.—In practice, headlighting is done with optical adjustments always departing from the ideal. The most serious departure is the size of lamp filament, necessitating a large part of it being out of focus. Mirrors are usually very near to the correct curvature, but are frequently displaced out of focus and also frequently used in halves as units, focused one before and one behind the true focus. Several corrective devices in the form of caps or prisms modify the beam between the source and the mirror. The most common corrective devices are traversed by the light after reflection from the mirror and form the front plate of the headlamp proper.

Prismatic devices may be used in any portion of the beam to vary the distribution of light in the beam by deflecting portions of it in the direction desired. Lens shaped correcting devices are also frequently used either to scatter the light or to modify its

distribution in the beam. These may be either spherical or cylindrical lenses, but in operation fall in two distinct classes;¹ those of the short focus, bull's-eye type, form secondary images of the lamp filament; from these images the light spreads laterally through the same angle within which the light falls on the lenses from the mirror. On the other hand,² cylindrical or spherical lenses of very low curvature merely modify the action of the parabolic mirror and do not form real secondary images, scattering the light.

In general, only rough calculations can be made of intensities of beam modified by correcting devices. The fractions of the beam which each intercepts may be integrated at any part of the beam in determining light distribution. In the case of prisms, the effect is on direction only, while lenses change convergence. Small lenses may produce all effects intermediate between the modification of concentration produced by lenses proper and the pure scatter produced by frosted or opal glass, according to their focal lengths.

Brightness and Glare.—By a well-known principle of optics the brightness of the front of a headlamp viewed from within the beam is the same (neglecting losses by reflection and absorption, 30 to 80 per cent.) as that of the light source itself, usually a lamp filament. This brightness of source in the case of a lamp filament, is in the range of between 500 and 1,500 l. This is hundreds of times the limit of tolerance (0.4 l., see table) for an eye adapted to the mean road brightness of 0.01 ml. and still more in excess for an eye adapted to the less illuminated surroundings. To avoid glare by cutting down the beam intensity by a factor of 1,000 would obviously render it of no value whatever as a road illuminant, so that the only course to pursue is so to direct the light that the passer never gets the beam proper in his eyes except perhaps for very short flashes, so short as not to produce blinding. Modifying the color of the light is by no means a remedy for the full beam glare although it may give slight relief in some cases of temporary glare.

Interference with vision, assuming fixed background conditions, depends not upon the intrinsic brightness alone but upon the product of intrinsic brightness and solid angle (area divided by distance squared) subtended. Now brightness times area is

flux and brightness times solid angle is flux density or illumination. Hence, from within any lighted space, the flux density in any direction is a proper measure of the interference with vision caused by any source of light in that direction. In the case of a headlamp viewed obliquely, the bright area is still of the same brightness as the source, but smaller in area. Beam candlepower and interference with vision are smaller in proportion to the solid angle subtended. The glare limit of interference with vision for an eye adapted to 0.01 foot-candle is about (see table) 400 ml. over the area subtended by a 9 in. (22.9 cm.) headlight at 100 ft. (30.5 m.) and considerably higher when the surroundings are nearly or quite unlighted.

Out-of-beam Illumination.—Some illumination outside of the main reflected beam is desirable to serve as signal lights for the passer and to slightly illuminate surrounding objects, relieving them of harsh contrasts for the driver. This light is chiefly supplied by that coming from the source directly through the front without being reflected from the mirror. If the front is a simple parallel sided sheet of glass, the results are quite satisfactory. The out-of-beam illumination at any distance from the headlamp is simply that of a lamp of that actual candlepower at that distance slightly decreased (20 to 50 per cent.) by reflection and scatter from the glass surface.

The filament of a small lamp can be viewed with entire comfort from a moderate distance. The *resolving power of the eye* is about $\frac{1}{2}$ minute of arc, that is to say, any fine detail however fine can not appear to the eye to have less angular width than $\frac{1}{2}$ minute of arc or 1 in 7,000. A lamp filament 4 ml. in diameter at 30 ft. (9.1 m.) distance subtends roughly two seconds of arc; hence will appear to the eye at that distance only $1/15$ th of its actual brightness. Since blinding effect is proportional to intrinsic brightness, while interference with vision depends on angular size as well as intrinsic brightness, neither blinding effect nor interference with vision can be very great in the case of a small filament lamp viewed from a distance of 30 to 100 ft. (9.1 to 30.5 m.).

When the *front glass* is not parallel sided, but is so formed as to produce the effect of multiple lenses, either cylindrical or spherical, then the out-of-beam lighting is very greatly increased

over what it would be if it came from the source direct. Each small lens forms an image of the light source as bright as itself and, if these images are multiplied, they throw a considerable portion of the light out of the beam proper instead of on the road where it is required, thus giving the driver much less light than he should have and throwing considerable light into the eyes of the passer where it may produce bad glare. The angular spread outside each little lens is equal to the angle of approach of the light to each lens on the inside.

When the front glass is *frosted* or *ground* in whole or in part, it simply means that so much of the light is taken out of the beam and scattered in all directions. Frosting is a very effective means of spreading the light through a wide angle.¹¹ The decrease in road illumination is very serious. The increased glare to passers by is not so serious on account of the angular area of the ground surface, but it represents almost a pure waste of light. The beam may be directed in practically any manner desired by means of small prismatic surfaces. Such prismatic surfaces never form secondary light sources as do strong cylindrical and spherical lens surfaces.

IV. PRACTICAL HEADLIGHTING.

Road Conditions.—While good headlighting would be by no means difficult on a perfectly smooth, clear road with no crossings, actual conditions are very difficult to meet satisfactorily. The best compromise barely meets the requirements of safety and requires a sacrifice of much of the pleasure of night driving.

To provide for actual road conditions, headlamps must provide adequate lighting without excessive glare on roads of all degrees of *curvature* up to right angles, roads of all degrees of *varying slope* both convex and concave, all sorts of road *margins* to be avoided when passing, from raised curbs to ditches, rough cobbles, brush, etc., safe illumination must be provided at *crossings*, the safety of *approaching vehicles* and pedestrians must be safeguarded, *sign boards* at various elevations must be illuminated sufficiently to be made legible and in some regions it is desirable even to provide illumination for boughs and other *overhanging obstructions*. *Street lights* vary the illumination

required and desirable while *dust, fog, rain* and *snow* profoundly modify seeing conditions and the requirements of illumination.

In regions where *curves* are common in roads, it is essential that the beam provided have considerable width since a sharply focused narrow beam is of little service. If the beam is confined below the horizontal, such illumination is readily provided without introducing bad glare conditions for passers. The three-quarter beam is very objectionable on roads with frequent curves. In the prairie regions of the country where nearly all roads are straight and cross at right angles, the beam need not be very much wider than the roadway itself.

In hilly country, the variation in slope of the roads provides one of the very worst conditions to be met in headlighting. In passing down through a concave portion the lighting is limited to the immediate foreground, leaving the driver at a disadvantage, while in passing up over a convex rise the beam projects too high above the road, producing, even with the best headlamps, bad glare in the eyes of the one approaching. No fixed headlamp can provide satisfactory lighting under such road conditions. The best compromise is probably the headlamp adjusted to give best lighting conditions on the level road. With tilting headlamps, easily controlled by the driver, proper illumination may be provided.

In driving on *rough roads* the angle of the headlamp is being constantly varied through an angle of 1 or 2°. This is sufficient to raise and lower the beam at 100 ft. (30.5 m.) by from 1 to 3 ft. (0.3 to 1 m.). These variations, however, are very quick and the effect is not serious on either driver or passer since the momentary flashes of but a fraction of a second are not nearly so dazzling as longer flashes.

A more serious condition to be met is the variation of the inclination of the vehicle body due to *shifting load*. Several persons entering or leaving the rear of the body will change the inclination of the headlamps by as much as 1 or 2° in most automobiles. Under such conditions it is difficult to adjust headlamps with precision to within 2 or 3 ft. (0.6 to 1 m.) at 100 ft. (30.5 m.) ahead. The best remedy for this condition is of course to adjust for average load distribution.

A difficult problem in headlighting is to provide safe illumination for *passing vehicles* on narrow roads. The very best illumination is required for safety in passing and glare can hardly be avoided unless the beam is limited to well below the horizontal. Illumination must have a reasonable spread since it is required on the left to avoid the passing vehicles and on the right to illuminate the margin of the road. In passing a vehicle in the same direction the same conditions obtain, but reversed. Safety for *pedestrians* requires fairly intense illumination extending well out to the margin of the road. The eyes of pedestrians are on an average of approximately the same height above the road surface as the eyes of the automobile driver. Hence, the limitation of the beam at its upper surface should be at the same height above the road.

For safety at *crossings* probably the best illumination is that which provides a brilliantly lighted road surface 50 to 100 ft. ahead of the vehicle and a considerable intensity just below the horizontal to illuminate a considerable distance ahead. Dust or fog of course adds to safety at crossings since both provide a brilliant pillar of light from the illuminating beam, but this factor can not be considered in headlighting, owing to widely varying penetration.

In the illumination of *sign boards* everything depends upon the position of these sign boards. It is of course highly desirable that these be situated low and if possible confined to within 5 or 6 ft. of the ground. It is doubtful whether the illumination of sign boards should be considered in any way in the problem of headlighting since, if properly situated, they would be best illuminated by headlights best meeting other requirements. For driving by daylight a higher position is desirable.

To provide high illumination for *road margins* it is almost necessary to provide other lamps than the headlamps. Spot lights are much in vogue for this purpose and serve very well if properly adjusted and directed. The illumination of *overhanging boughs* and other obstructions is the chief service to be rendered by the upper part of the three-quarter beam. It is, however, very doubtful whether such obstructions are of sufficiently frequent occurrence, except in very limited localities, to be worth consideration in headlighting.

In driving on *lighted streets* preferences as to headlights vary widely. On well lighted streets there is little to choose between having headlights entirely out and having them full on. The favorite arrangement, and a very good one, is to switch the current to small auxiliary lamps on the upper part of the reflectors which provide a well spread illumination immediately in front of the vehicle, but practically no light and no glare at a distance ahead. It is doubtful whether the street light factor should be considered in the design or adjustment of headlamps.

To deal with *dust, fog, rain* or *snow* which obstruct the light and produce serious veiling glare very little can be accomplished. Aside from the collection of light scattering material on the windshield, these obstructions seriously interfere with both illumination and vision. The dust or fog illuminated by the beam produces bright veiling glare in looking through the beam at the road surface. Above the beam, the unilluminated dust or fog obscures vision by scattering and absorbing light which would otherwise reach the eye.

Either bright or dark veiling is powerful in suppressing contrast and therefore interference with vision. There is no remedy for it since contrast can not be increased or decreased by varying the intensity and, except when objects are highly colored, not by using colored light. Since the observer and part of his visual path are in darkness, increasing the intensity of a headlight, particularly by good focusing, considerably enhances the "boring" effect, or apparent penetrating power, of the headlight. With bright veiling glare, if the illumination is too greatly increased, the blinding effect is out of proportion to the increased visibility of contrast.

In case the scattering particles are very small, approaching light waves in dimensions, using illumination of longer wave length is very effective in securing greater penetration. Since red is low in visibility and requires special focal adjustment in the eye, it is usual to compromise with yellow or amber light since this is of high visibility and the visual adjustment is the same for yellow as for white. Fog not containing dust and rain and snow are non-selective as regards color and the yellow light is not so effective.

Illumination is provided for these various road conditions in a

wide variety of headlamps and modifying devices designed to provide adequate illumination under all ordinary road conditions without serious glare of any considerable duration in the eyes of any passing driver or pedestrian. These various devices are of three general types: (1) special front glasses, (2) special mirrors and caps and (3) devices for dimming and tilting headlamps. Twenty-five of the better known devices are described by Little.¹ A critical study of headlamp design from the engineering standpoint has been published by A. L. McMurtry.¹³ We shall here discuss the various devices by groups from the standpoint of effectiveness in obtaining the results desired.

Dimming and Tilting Headlamps.—In the dimming devices, the current in the headlamps is under control in one of three ways: (*a*) reduced to approximately one-half, (*b*) turned entirely off, leaving only the sidelights and (*c*) switched to an alternative pair of filaments of lower output and out of the focus of the mirror. All three may effectively eliminate glare, but (*a*) and (*b*) are certain to be unsatisfactory because of the lack of sufficient road illumination; (*c*) is generally unsatisfactory for the same reason except on partly lighted streets. None of these devices are to be recommended even from the standpoint of eliminating glare because it is certain that any such control of operations left to the discretion of the driver will be neglected where such operations bring about greatly increased difficulty to the driver in seeing the road or greatly increased trouble in operating his car in difficult situations.¹⁴

Permanently *tilting* the headlamps downward by an angle equal to half the angle of the beam, if the beam is carefully focused, is nearly as effective in the elimination of glare as any method which does away with the upward light to the same degree. It is open to the objection that it does not give the best distribution of illumination on the road. The individual preferences in the permanent adjustment of fixed headlights are many and various. A common one and a good one is to center the left hand headlight on the road at about 75 ft. (23 m.) straight ahead and put the beam from the right hand lamp on the same spot. Others prefer to center both lamps on the road at a distance of 100 ft. (30.5 m.) or more. Still others prefer both beams centered to the right of

the road. For safety in passing, however, the first mentioned arrangement shows many points of superiority over the others.

Headlamps capable of being tilted by the driver can be operated very effectively to give no glare with higher road illumination under nearly all road conditions. This plan of course is also open to the objection that its success in operation is dependent upon the skill and attitude of mind of the driver.

Special Mirrors and Caps.—Various forms of split mirrors and mirrors of silvered meniscus lenses permit of various distributions of light within the beam when the lamp filament is sufficiently concentrated. Split mirrors make use of the fact that, when the lamp filament is in front of the focus of the mirror, the light reflected by the upper half of the mirror goes into the lower half of the beam while, if the lamp filament is back of the focus, it goes into the upper half of the beam. Hence, by splitting the mirror in a horizontal plane and displacing the upper half backward, if the lamp filament is placed between the two partial foci, all of the light will be thrown in the lower half of the beam. If the two halves of the mirror are of different focal length, of course the same result can be obtained without displacing one half relative to the other. Split mirrors are used departing from the ordinary paraboloidal form in one or both halves in order to vary the distribution of light in the beam. Various forms are capable of giving very nearly ideal distribution, but all require very concentrated lamp filaments very precisely adjusted. A sharp cut-off at the upper side of the lower half of the beam is particularly difficult to obtain with this arrangement.

Various forms of *lamp caps* are designed to reflect or refract the light which would eventually go into the upper half of the beam into the lower half, in effect, therefore throwing the upper half into the lower half. Theoretically, this is an ideal procedure and, when applied in practice to lamps having very concentrated filaments and carefully focused, excellent results may be obtained.

Special Front Glasses.—In conjunction with a simple paraboloidal mirror a great many forms of specially designed front glasses provide a wide variety of distributions of beam illumination. The front glass is the favorite device because of its simplicity, effectiveness and ease of operation. The most serviceable types require a concentrated source and fairly good adjust-

ments to give the beam distribution intended. Many of those on the market are more ornamental than useful and some, all things considered, are not as good as plain fronts. Good results may be secured with merely prismatic departures from parallel surfaces. Such front glasses do not produce secondary images outside the glass, which, being approximately as bright as the source itself, may give very bad glare to passers. Spherical or cylindrical surfaces of short radius are to be condemned in that they are all wasteful of the light in the beam and that they form intense secondary sources, producing objectionable glare at considerable angles from the axis.

While the special devices mentioned above, if properly constructed and adjusted in position in conjunction with a suitable source of light, may give excellent road illumination under average road conditions, in actual practice, it is found that fully half the trouble from defective lighting could be obviated by the proper adjustment of the devices actually in use. It is not uncommon to see headlamps directed upward so that none of the light reaches the road and all of it would produce bad glare to a passing driver. Probably not one lamp in ten is properly focused. A campaign for special devices should be preceded by a campaign for proper adjustment.

V. SAFETY LIMITATIONS.

It is the function of headlighting legislation to insure public safety by setting fixed limits both to road lighting and to glare. In this section is given a summary of the limits considered essential and desirable by this Committee. This set of limitations is necessarily very different from the set of specifications for ideal lighting (section 2) having to do with the safety, comfort or pleasure of the driver alone.

1. *Discretion of Driver.*—The ideal lighting system as outlined in a previous portion of this report can perhaps best be obtained where some features of operation are under control of the driver. However, a system depending for its effectiveness upon the discretion of the driver is objectionable in that through ignorance, carelessness or malice on the part of some drivers such a system will not always be properly manipulated. Many drivers would obey the law only in the presence of an officer. Whether or not this disadvantage is sufficient to warrant the sacrifice of the

advantages inherent in a controllable system is still an open question to some members of the Committee. A serious objection to permitting such discretion is the difficulty of obtaining evidence against an offender. Conviction on such evidence would involve proof of the condition of the headlight at some previous time and, if this condition were merely relative, in law no witness would be competent. While each member of the Committee would favor headlamp systems under the control of the driver so far as comfort, pleasure and to some extent safety are concerned, allowing such discretion would involve difficulties in enforcing the legislation which would be required.¹⁴

2. *The Headlight Beam*.—No headlight should be permitted such that the reflected or beam light is projected above a plane 42 in. (10.7 cm.) above the road and parallel to it, measured 100 ft. (30.5 cm.) ahead of the vehicle. We do not consider it advisable to place a maximum limit upon the lateral spread of the beam provided it is confined to below the 42 in. level. Permitting light in the upper right hand quadrant of the beam is still favored by some, but the majority of your Committee favor limiting the beam to the lower quadrants, particularly in districts having numerous curved roads. The beams from spotlights should be subject to the same limitations as those from headlights.

3. *Scattered Light*.—No light above the horizontal should be tolerated which, at 5 ft. (1.5 m.) above the road surface, is of more than a certain candlepower. This committee favors a limitation of this form, but considers that the precise candle power specification should be subject to such modification as may seem desirable in the light of further experimental work. So much depends upon the type of lamp filament, its precision of mounting, the perfection of the mirror and the form of front glass that, without further investigation, your committee is not yet prepared to state what minimum limit is to be recommended. The sharpest practical cut-off is desirable to minimize glare on country roads, since with dark surroundings the retina is so sensitive as to be easily blinded. The practical limit is of the order of 100 to 500 candle-power 1° above the horizontal or 5 ft. (1.5 m.) above road level at 150 ft. (46 m.). The 5 ft. level is specified rather than the usual 42 in. (107 cm.) level since we are concerned with glare chiefly at the average height of the eyes of pedestrians and the drivers of approaching automobiles.

4. *Minimum Illumination*.—No driving should be permitted where the road illumination provided is less than 0.001 f.c. This limitation, of course concerns chiefly the safety of the driver himself, but also the safety of pedestrians and the occupants of unlighted horse-drawn vehicles.

5. *Minimum Spread*.—The normal illumination provided at distances from 50 to 100 ft. (15.3 to 30.5 m.) ahead of the vehicle should not be less than 10 ft. (3.1 m.) in width upon the road surface. With a sharply focused narrow beam and very little scattered light, passing other vehicles is dangerous because such a beam cannot illuminate both the vehicle passed and the edge of the road on that side.

6. *Colored Headlights*.—The use of white headlights should never be legally required since it can not be enforced. Even with uncolored headlights no source of light even closely approaches white. Aside from the slight and unimportant color distortion, your Committee finds no objections to the use of the yellow or amber colored headlights.

Your Committee have attempted in this report to present only such matter and make such recommendations as it could reach substantial agreement upon and at the same time not omit the consideration of any point upon which it could be expected to report. Although a report of this nature could not be prepared in a few weeks or even months, we believe we have finally carried out the instructions of the Council to "prepare a statement of principles and data for use by" other committees. We have endeavored to prepare just the data required by (1) automotive engineers in designing lamps, caps, mirrors and lamp fronts to produce the illumination specified and (2) committees on lighting legislation for the preparation of effective legislation based upon both scientific principles and good practice.

P. G. NUTTING, *Chairman*,
C. O. BOND,
WILLIAM CHURCHILL,
J. R. CRAVATH,
E. J. EDWARDS,
W. B. LANCASTER,
W. F. LITTLE,
S. C. ROGERS.

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DISCUSSION.

ARTHUR H. FORD: The Committee is to be congratulated on the clearness and completeness of this report, which settles many controverted points. The prominence given to "beam candlepower" is to be questioned. Owing to the fact that the beam of light in front of a headlamp provided with a reflector or lens, is a series of cones having their apices at various distances from the lamp, the apparent beam candlepower can be varied through wide limits by locating the photometer screen at varying distances from the lamp and multiplying the illumination intensity on it by the square of the distance from the lamp. The illumi-

nation intensity at a specified distance from the headlamp would seem to be a better criterion by which to judge.

The proposal to limit the height of the reflected beam by specifying the maximum illumination intensity permissible above a certain height, as 42 in. at a distance of 100 ft. in front of the headlamp, is to be commended; as this is the only kind of a limitation that is readily enforceable.

J. R. CRAVATH: In considering the report of this Committee some emphasis should be placed on the fact that it deals with principles rather than specific requirements and that the making of definite specifications designed to reduce the glare evil, which is the point of most practical importance at the present time, is left to subsequent experiments which this Committee was not in a position to carry out. These experiments are at present writing being carried out by a subsequent Committee. The writer's study of this subject has convinced him that there are so many variables which must be considered in a scientific analysis of this subject that it is practically hopeless to arrive at a definite specification as to the candlepower or illumination to be permitted at the eye level at a given distance by such analysis or by any method other than the empirical; that is by actual trial on the road, with automobiles driving past each other as in practice, with headlamp beams giving a known measured illumination within the glare zone or at eye level. Results from a sufficient number of such practical tests will give us results sufficiently reliable for legislative specifications as to the illumination or candlepower permitted within the glare zone.

F. H. MURPHY: This is indeed a very timely report and I much appreciate the work of the Committee. From the general attitude of the automobile owners in this section of the country, relative to our attempt to improve the automobile headlamp situation, I feel certain that there is a positive demand for intelligent legislation regarding this matter. The large majority of drivers will undoubtedly welcome something concrete which will improve present conditions, although there will always be varying opinions regarding the proper limits of glare in illumination. The greatest opposition to any legislation will, however, arise

not from the great body of earnest, intelligent drivers but such selfish interests as manufacturing establishments whose products clearly will not meet the requirements of any sane legislation and from that species of driver, commonly known as the "road hog," neither of whom have any interest whatever in the public welfare. In fact intimations have already been made as to what may be expected.

Past legislation in this section has in general been so hazy that neither the judicial nor executive officers had a clear idea of what constituted a violation of the laws in many cases. As a result of the general dissatisfaction because of certain arrests and judgments pronounced which were often manifestly unjust the sheriff of the county and the chief of the police of the city decided to leave the matter of what should constitute a violation of the existing laws to the opinion of a competent committee and to be governed by its decision in making future arrests. Such a committee consisting of the sheriff, the chief of police, chairman of the Public Safety Commission, a representative of the county commissioners, a representative of the city council, an illuminating engineer and three or four representatives of the various automobile organizations, dealers, accessories, etc., was selected, which after due deliberations made some general recommendations. The one section of the existing law which seemed to give the greatest trouble was relative to glare. It read as follows: "No operator of any motor vehicle shall use a headlight unless it is so shaded as not to blind or dazzle other users of the highway or make it difficult or unsafe for them to ride, drive or walk thereon." The Committee then reported in arriving at a decision as to what will constitute a glaring headlight in accordance with the terms of the present ordinance and in the absence of any extensive set of tests, the following general conditions are agreed upon:

"A headlight will not be considered glaring when the surroundings of the headlight can be seen unaccompanied by a halo, if the driver can look at the approaching car and readily see objects between it and himself.

"The size of lamp permitted in any headlight must not exceed 27 candlepower.

"The size of lamp permitted in headlight falling under subdivision 2 of the non-controlled light class as defined hereafter must not exceed 18 candlepower.

"Headlights will be divided into two general classes, those having controlled lights and those having non-controlled lights.

"A headlight to be included in the controlled light class must direct the majority of its light upon the level roadway below an imaginary horizontal line drawn through the center of the headlight. This may be done by tipping either the entire headlight or the reflector and lamp equipment so that the center of the cone of light from the headlight shall strike the level roadway not to exceed 75 ft. beyond the machine or it may be accomplished by means of lens glass front used on the headlight which by means of their construction direct the majority of the light below the horizontal.

"All other headlights will be included in the non-controlled light class. Under this class two subdivisions are considered. Subdivision 1 to include those headlights with clear glass fronts and subdivision 2 those which by means of diffusing glass fronts, special screens or specially designed reflectors decrease the light thrown above the horizontal to a certain extent in an attempt to eliminate objectional glare.

"All headlights falling under subdivision 1 of the non-controlled light class must have the lamps controlled by means of dimmers and they must be fully dimmed when driving on lighted streets or roadways or when within less than 200 ft. of an approaching vehicle on unlighted streets or roadways.

"Those falling under subdivision 2 of the non-controlled light class must as stated previously not use lamps with greater than 18 candlepower.

"Machines desiring to use spot lights must have same mounted upon the left hand side of the machine and lights must be so adjusted that the center of the light cone will strike a level roadway not over 75 ft. ahead of the machine and to the right of the center line of the machine."

The various lenses sold in the local market were then classified in accordance with the divisions. The classifications thus made by the Committee were more or less unsatisfactory because they were made without specific tests and to avoid as much friction as possible temporarily until something satisfactory in the way of legislation could be enacted. With that end in view the illuminating engineer was asked to draft, for presentation to the general Committee, a proposed law which could be submitted to the various legislative bodies to enactment. The purpose of the law was to minimize the glare of headlights; provide ample illumination for safe driving, both from the standpoint of the driver and of the public; to be reasonable in its requirements; and finally to be clearly expressed.

Thanks to the work of Mr. P. G. Nutting and his Committee, as well as to the information obtained from tests recently made in New York by representatives of the Illuminating Engineering

Society and the Society of Automotive Engineers, the local report may now be prepared with much greater intelligence and confidence than would have been possible a few months earlier. The success which our somewhat primitive efforts has met thus far is indeed gratifying. For a time the police department conducted a sort of a testing station where any owner could come with his machine and have suggestions made to him as to what was necessary for him to do in order to comply with the law. In fact in many cases the adjustment would be made at the time. Recently, however, the station has been dispensed with and at present there is a commercial station which for a small fee will properly adjust the lights in accordance with the present ruling. One of our greatest sources of trouble seems to be the use of high candlepower lamps with diffusing glass front for the headlamp. Another source of trouble is improper adjustments of the focus of the lamp and the alarming lack of knowledge on the part of the majority of garage men as to how to properly focus the lamp. It is not surprising that an owner would be ignorant of this fact, but that the men who are paid for caring for the machines should also be ignorant is unfortunate. There is indeed need for an educational campaign.

There is no doubt that one of the most important problems before us at the present time is a satisfactory solution of the headlamp situation and whatever compromises may finally be agreed upon they should be nationally adopted. It would seem that such a purpose could best be accomplished through concerted action of such national organizations as the Illuminating Engineering Society, the Society of Automotive Engineers and others who are vitally concerned in this matter. Another unfortunate condition is the tendency nowadays of manufacturers to equip the cars with certain patented devices presumed to improve the lighting features but which in reality are often the most flagrant transgressors of law and reason. If manufacturers could be persuaded through the influence of these national organizations to equip their cars only with clear glass fronts for headlamps until such a time as a general agreement is reached regarding what shall constitute a proper headlight it would greatly simplify and improve matters.

DR. NUTTING (In reply): We have attempted in the present report to co-ordinate the various phases of the headlamp problem, namely, the properties of the retina upon which visibility and glare depend; (2) the optical problems involved in the design of headlamps; (3) the practical road conditions complicating the simple headlamp problem, and (4) the legal limitations necessary and sufficient for the public safety.

Our data on the properties of the retina cover a wide range of flux densities and include those met with in automobile driving. The uncertainty is in the choice of a discrimination limit corresponding to actual requirements. For lack of practical road measurements we chose the brightness 0.01 ml. as a tentative value, this giving half the discriminating power of full illumination. Possibly half of this would be esteemed sufficient by the majority of drivers under most conditions. This question will not be settled until a great number of observers have made actual road tests under a wide variety of lighting conditions, as Mr. Cravath has pointed out. However, conclusions from such measurements should be drawn with care since they will be profoundly influenced by such accidental factors as the illumination of surroundings, nature and color of test objects and previous exposure of observer.

As to the practical means of securing better headlighting with less glare, most important of all is to secure proper adjustment of the devices already in use. From my own observations, I should judge that hardly one headlamp in ten is properly adjusted to give the best results it is capable of giving. After adjustment, of course improvements in design are in order and in this case the real trouble maker is the lamp filament, since the mere replacing of the lamp bulb may throw the headlamp system from the highest to the lowest class of adjustment. A few hundredths of an inch in the region of the lamp filament will throw the beam several feet laterally 100 ft. ahead of the lamp.

Improvement is to be looked for in practice therefore, first in the careful adjustment of existing headlamps, secondly in improved and more uniform lamp filaments making still more careful adjustment possible and finally in such legislation as will compel automobile drivers to use good lamps and keep them carefully adjusted.

WARD HARRISON (Communicated): In reading page 280 of this report I was surprised to note the decided stand which the Committee has taken against the use of lights controllable at the discretion of the driver. The only objection advanced against a system of this kind seems to be based on the premise that a large proportion of the automobile drivers will have no regard for the law unless punishment for its violation is a certainty. To this I cannot agree. I have driven for a number of years in a state where adjustable spot lights are very generally employed, and I can recall but two occasions in all of the thousands of times when I have passed vehicles so equipped, that the light was allowed to shine in my face.

It is true that to-day there are many headlights operated without any provision whatsoever against glare, but I believe that this is due in the main to the fact that some people will not spend money or anything unless they have to; and further, that some others have not found any anti-glare device which they consider sufficiently satisfactory to purchase. Assuming that the law required that every headlight be equipped with some form of anti-glare device, controllable or otherwise, it is safe to say that of those who chose the adjustable lamps, the overwhelming majority would prove themselves considerate of their fellow-travelers. If anyone were so far forgetful as to leave his lights directed in a manner objectionable to the driver of an approaching vehicle, the latter would have a ready means of reminding him. The fact that many drivers habitually exceed the speed limit has been cited to support the claim that they would also disregard the headlight law if possible. The point of difference is that in the former case they do not feel that they are directly endangering or inconveniencing anyone else. In the case of the improperly directed headlight the inconvenience is obvious.

Sometimes there is a tendency to exaggerate the glare menace. If a driver is really afraid to proceed against a pair of glaring headlights he can always protect himself by coming to a stop on his own side of the road, in which case he has the absolute assurance that the other man can see how to avoid him. When walking on a country road one welcomes the automobile with powerful lamps, because it gives ample warning of its approach.

Safety from the standpoint of the man behind the headlights must also be considered. After having experimented with many headlight devices I have never found any except the adjustable type which really makes driving over unfamiliar country roads altogether safe after nightfall. In touring one often traverses many miles of road where vehicles are passing but infrequently, and where a level stretch of pavement is the exception; certainly under these conditions the risk of accident is much reduced if a headlight device can be used which projects its beam far ahead of the car and which can be adjusted to take care of changes in grade. It is only with a headlamp which is capable of throwing a considerable volume of light above the horizontal that sharp turns and obstacles in the road can always be distinguished at a safe distance.

DR. NUTTING (In reply to Ward Harrison): I think every member of the Committee will agree with Mr. Harrison in his argument in favor of the controllable headlamp as stated on page 281 of the report. However, the section of the report to which he refers (paragraph No. 1, "Discretion of Driver," under Section V, "Safety Limitations") deals with the legal requirements of the headlamp situation. Laws are made to protect the public against the very small percentage of inconsiderate or reckless individuals and if any law is to be drafted to deal with this situation it should be so drawn as to be capable of enforcement against the very small percentage of automobile drivers who would violate it.

Possibly the objections to the controllable headlamp were not stated at sufficient length in the report. The question of enforcing a law depends upon the collection of evidence and if a device is capable of quick adjustment over a wide range, it might easily be adjusted after the offense was committed and no witness would be competent to positively state what condition it had been in at some previous time. Therefore, no convictions could be obtained and the law would be unenforceable. Hence we state in the report that, while we favor such adjustable control, it was not considered feasible to draft enforceable legislation covering such control.

We would all appreciate the increased freedom of operation of the illumination provided and the added comfort and pleasure in driving which it permits, but I personally doubt very much the feasibility of drafting headlamp laws which will obviate the misuse of adjustable headlamps.

THE FOOT-CANDLE METER.*

BY C. F. SACKWITZ.

Synopsis: The following paragraphs contain a description of the *foot-candle meter*. This is a small portable self-contained device for measuring illumination, which has been developed from a design originated by Dr. Clayton H. Sharp. The foot-candle meter is contained in a japanned metal case $7\frac{3}{4}$ in. by $5\frac{3}{4}$ in. by $1\frac{1}{2}$ in. (19.7 cm. by 14.6 cm. by 3.8 cm.) and weighs about 3 lbs. (1.36 kgm).

Every illuminating engineer is familiar with the various portable devices for measuring illumination which are on the market at the present time. Those best known and possibly most universally used are the Weber photometer, the Sharp-Millar and the Macbeth illuminometer. At this point let it be understood that the foot-candle meter was not designed to take the place of these instruments, but to render a service heretofore not readily obtained from them.

At the meeting of the Association of Edison Illuminating Companys at Hot Springs, W. Va., on Sept. 4-7, 1916, Dr. Clayton H. Sharp exhibited a working model of a small self-contained instrument of the illuminometer type which embodied the one distinctive feature of being equipped with a foot-candle scale which could be read without the manipulation of any moving parts.¹

Mr. S. E. Doane was present at this meeting and had the opportunity of inspecting the small illuminometer. He at once realized the many advantages that could be obtained from the use of an instrument of this kind if placed in the hands of lamp salesmen, for, due to its possibilities of small size, light weight and simplicity of operation it gave promise of opening an entirely new field of practical photometry, where the larger and more precise instruments were not available and where the desired accuracy of the measurements was not such as to necessitate their use.

With this in view arrangements were made so that the device

* A paper presented before a meeting of the Pittsburgh Section of the Illuminating Engineering Society, held in Cleveland, Ohio, December 14, 1917.

¹ This is described on page 569, *Electrical World*, Sept. 16, 1916.



Figs. 1 and 2.

Fig. 1.—The foot-candle meter, meter case and descriptive booklet.

Fig. 2.—The light box.



Figs. 3 and 4.

Fig. 3.—Complete light box equipped with scale.

Fig. 4.—Location of various parts of the foot-candle meter within the case.

could be taken over, developed and manufactured for the use of the various lamp interests in the promotion of lamp sales.

The foot-candle meter in its present form, Fig. 1, consists of five principal parts, namely—

The metal case

The light box (containing the photometric scale, diffusing screen, and comparison lamp)

The flashlight battery

The rheostat

The voltmeter

The light box is shown in Fig. 2. It is composed of a pressed metal box about $6\frac{3}{4}$ in. (17.2 cm.) long by 1 in. (2.5 cm.) wide and 1 in. (2.5 cm.) deep at the end containing the comparison lamp and about 1 in. (2.5 cm.) wide and $\frac{1}{2}$ in. (1.3 cm.) deep at the opposite end, and is lined throughout with white blotting paper. The comparison lamp is located at the large end of the box and directly in front of it is placed a ground glass diffusing screen. Over the remaining opening is placed the photometer screen. This is composed of a strip of clear glass about $5\frac{1}{2}$ in. (14 cm.) long by 1 in. (2.5 cm.) wide over which is pasted a piece of semi-opaque white paper through the center of which is punched a series of $\frac{1}{8}$ in. (3.2 mm.) round holes equally spaced throughout the entire length. Over this is pasted a thin sheet of translucent paper commonly known as *berkshire* paper. If this screen is held with one side toward the light and viewed from the opposite side the parts of the paper from which the holes have been punched appear much brighter in contrast with the rest of the background but if held in such a position that the illumination falling on both sides of it is of equal brightness the round spots practically disappear from view.

It is this principle that is made use of in the foot-candle meter. The comparison lamp located in the extreme end of the light box illuminates the interior of the light box, brightly at parts close to the screen and gradually decreasing toward the farther end of the box, the rate of decrease in illumination varying inversely between the second and third power of the distance from the screen. Fig. 3 shows a complete light box equipped with a scale ranging from 0.5 to 25 foot-candles.

Certain features of the remaining units in the assembly are

worthy of brief mention. The battery is a standard three-cell flashlight type chosen because of its small size and availability for replacement. The higher voltage of the three-cell battery permits of the use of an advantageous design of comparison lamp. The rheostat had to be a new and special design because no available design met the requirements of reliability and strength. The voltmeter is also unusual for a small instrument in that it contains over 100 ohms per volt of scale reading. This high resistance seemed necessary in order to get a high ratio of total to moving coil resistance, thereby allowing a performance little affected by changes in temperature. The high resistance of course has the added advantage that it avoids adding unnecessary load on the battery. The open back view of the foot-candle meter, Fig. 4, shows the various parts and their respective locations in the pressed metal box.

There are yet many possible tests concerning the accuracy of the instrument which have not been made. Certain data, however, have been obtained, and the indications are that if the foot-candle meter is carefully used under conditions not involving too great a color difference, the results obtained should be accurate to within about 15 per cent. This pertains to measuring illumination from such light sources as carbon, vacuum tungsten and gas-filled tungsten lamps. In measuring illumination from gas-filled tungsten "daylight" light sources, a group of nineteen different observers showed an average error of about 32 per cent., the readings taken on the foot-candle meter being lower than the actual illumination. This is not unexpected for in reading illumination where so great a color difference is involved, considerable difficulty is experienced even with the most elaborate instruments, individually calibrated by each observer.

As a check on the above data the illumination at these same flux stations was measured by two observers with a well-known portable photometer which had previously been calibrated by a third and disinterested person. This was using the portable photometer under practically the same conditions as the foot-candle meter. The following results may be of interest.

FOOT-CANDLE METER.

Observer	Carbon per cent. error	Vacuum tungsten per cent. error	Gas-filled tungsten per cent. error	Gas-filled "daylight" per cent. error
D. C. H.	+8.	+18.	-8.	-17.
C. F. S.	+4.	+ 8.	-8.	-22.
Per cent. error of average	+6.	+13.	-8.	-20.

PORTABLE PHOTOMETER.

D. C. H.	-6.	+3.	+12.	+36.
C. F. S.	+10.	+4.	+15.	+11.
Per cent. error of average	+2.	+4.	+14.	+24.

It should be understood, however, that the above figures simply show the results obtained by making a few rough comparisons between the foot-candle meter and the more precise portable photometer with a view of showing that some errors which may be attributed to the inaccuracy of the foot-candle meter may really be due to the individual characteristics of various observers, and to the fact that the foot-candle meter is not "checked up" or calibrated by the person who is to use it, as is generally the case with the more elaborate portable photometers.

It is also reasonable to believe that in the case of any one making frequent use of the foot-candle meter, and having access to a standard of candlepower of some kind, greater accuracy could be obtained if the scale were actually calibrated at various points to fit that persons particular judgment of the various foot-candle intensities on the scale. This could even be done in cases where it was desired to measure illumination which differed in color with that of the foot-candle meter, for even though this so called "checking up" or recalibrating would involve the expenditure of a little more time on the part of the user there will be found many cases where the foot-candle meter, due to its extreme portability and simplicity of operation, will be found to render a service heretofore not obtainable.

Perhaps the uses for which the foot-candle meter is particularly adapted are obvious but it may be of interest in conclusion to cite an actual occurrence which was just recently brought to the attention of the writer.

The master mechanic in a large railroad shop began complain-

ing of the poor illumination in his office a year or so after the illuminating engineer had provided him with a new system computed to give 8 foot-candles on his desk and table. The suggestion was made that he try cleaning the lamps and reflectors. This was not done because of lack of confidence in the suggestion of the illuminating engineer, prompted by his own judgment that the units appeared to be reasonably clean.

The engineer exhibited a foot-candle meter and secured the interest of the master mechanic in noting measurements which showed that he had only 4 foot-candles where there should have been 8. His interest in the measurements were such that he agreed to have the units cleaned at once. When the first of the four units was cleaned the scale of the foot-candle meter promptly showed 5 foot-candles, and finally when the last unit had been cleaned the scale showed 8 foot-candles. Needless to say the master mechanic was convinced of the necessity of cleaning lighting units in his office and also throughout his shops periodically, no further arguments being necessary in the face of the story told by the foot-candle meter.

Had it been necessary to make the above test with one of the more precise types of illuminometers it is doubtful if the results would have been as convincing, for the average person outside of those engaged in illuminating engineering does not understand the operation of such complicated apparatus and is likely to lack faith in the results. With the foot-candle meter the results are obvious since they are obtained directly from the scale and can be read nearly as well by the layman as the experienced engineer.

In general it may be said that present indications are that the foot-candle meter will prove to be of great value in making illumination measurements where extreme accuracy is not essential but where it is necessary that the customer be thoroughly convinced of the lighting conditions in his establishment. With this assistance the engineer and salesman should have less difficulty in talking good lighting in terms of tangible units capable of demonstration.

DISCUSSION.

MR. SCOTT: I am very much interested in the instrument which Mr. Sackwitz has described, principally from the stand-

point of promoting the use or advertising the use of a high degree of illumination in various industries. I think that the engineers who developed this little device have given us a beautifully self-contained apparatus, and one that no salesman who is selling better light can fail to appreciate. I do not know how much I ought to lay stress on that feature, though, because I do not know how readily available that instrument is at the present time commercially, but I cannot refrain from saying that when they are generally available that they will be found a great tool in the hands of the commercial men. Thousands of dollars are spent every lighting season by the different interests in trying to educate just such men as Mr. Sackwitz mentioned (the master mechanic), to the need for greater illumination in the shop, and the ways of securing it, not only by keeping units clean, but by using higher wattage units where the present units are insufficient, and actual visual proof is a whole lot more convincing than where you have to take the salesman's word upon it. One other point: if I were a salesman using this device, without seeming to be captious at all, I do not think I should use the name foot-candle meter in taking it up with the customer. That is a very accurate name and an excellent name for us who understand just what is meant by it. Considering it in a technical sense, it fits admirably, but it seems to me that there is certainly a psychological effect that the word "meter" has on the average man, that tends to make him afraid that the more light he uses the more it will cost him. In his mind he will be measuring dollars and cents while you are measuring light, whereas if you call the instrument an "indicator," or perhaps an "*illumination* indicator," you would steer clear of the prejudice against meters. Simply show the prospect that you are indicating the degree of illumination, which is, after all, what he wants. He is not particularly interested in foot-candles—in fact he does not, as a rule, know what a foot-candle is. Moreover, the word "candle," as a unit, is falling into more or less disuse. The term "foot-candle" tends to perpetuate the candle in the popular mind. Even in our own discussions, might it not well be superseded by the term "lumens per square foot"?

It seems reasonable to assume that in using Mr. Sackwitz's device commercially, a better impression will be created by call-

ing it an indicator, and as a nickname the "illumination indicator" is suggested for individual consideration.

F. E. CADY, Cleveland: It is an interesting fact that the engineers who have devised this instrument have made practical use of a principle employed as far back as 1894 by Trotter and referred² to by him as "not likely to be required except for researches."

There is one technical point which struck me as Mr. Sackwitz was describing the instrument which may or may not have any significance, and that is the use of a small raised spot on the resistance. From the little experience we have had with resistances of the type where contact is made by a spring we have found that there is a tendency for the spring of the arm in time to weaken and I should think that if when the arm came to the point where contact was to be broken it was raised or forced up that that might in time weaken the spring and cause trouble in making contacts. I would like to ask whether there is any particular advantage in that over the type which is quite common of having the arm come to rest at the end on a contact which is not connected in any way with the series, but which is at the same height as the other parts of the resistance?

E. J. EDWARDS, Cleveland: Mr. Sackwitz mentioned that the uses for the instrument probably were quite obvious. A great many of them are, but there are some which were not anticipated. An example is the use in making beam candlepower measurements of *automobile headlights*. The automobile headlight problem is one of considerable interest to illuminating engineers and others at the present time, and the foot-candle meter has already been considerably used for the checking and studying of experimental headlights. The Department of Streets and Sewers of the City of St. Louis is using one of the instruments in connection with other equipment for the inspection of owners' cars which are questioned as regards complying with the law. It was a long time before people could agree that automobile headlights could be properly specified in terms of beam candlepower, but now that agreement seems to exist and is desirable to have some

²"Illumination, Its Distribution and Measurement," by A. P. Trotter; MacMillan & Co., 1911.

ready means of measuring the intensity. The foot-candle meter is an advantageous instrument for that purpose because it is so easily used, for this, in particular, is a case where extreme accuracy is not necessary. By standing in a position in front of the headlight and choosing a distance so that the illumination comes within the limits of the scale, and then multiplying by the square of the distance, the beam candlepower to sufficient accuracy for most all necessary purposes in automobile headlight testing is obtained.

Commenting on the name chosen for the foot-candle meter, illumination indicator was the first name considered. As a first impression, any word with meter tacked on the end seemed objectionable because of a technical sound and the possibility of a resulting undesirable impression among salesmen and others who might be shy of a new instrument with a high sounding name. But meter isn't quite so high sounding as it used to be. Most people now are familiar with automobiles equipped with ammeters, motometers, etc., and these meters are more indicators of a condition than they are precision measuring instruments. The name "foot-candle meter" well describes the instruments and there has so far been no evidence of the handicap expected by Mr. Scott.

W. P. HURLEY, Pittsburgh: 1. One particular application of this instrument which has come to my attention is its use in factories where machines or other large objects on the floor are shifted during the day between tests made on successive nights. At times it is impossible to get a sufficiently extended test in one evening with the older photometers, necessitating the work being repeated after the apparatus on the floor had been moved. The foot-candle meter would greatly increase the chances of getting such work completed at one time.

2. The personal equation involved in the percentage of accuracy is not clear to me. By this, I mean the percentage variations one unaccustomed to the foot-candle meter would get from his observations with a photometer to which he had been accustomed and with which he obtained approximately correct results. Is it advisable to check the foot-candle meter against the photometer to accustom an operator to its correct reading?

3. Considerable explanation was made of the temperature effects in the voltmeter used with this instrument, which leads me to ask as to the possibility of using an ammeter.

DR. E. P. HYDE, Cleveland: Possibly as a member of the Committee on Nomenclature and Standards I may be pardoned for answering one point which Mr. Scott has raised regarding the name suggested by the authors. He speaks of the term "candle" becoming obsolete. It is true that an effort is being made to place the emphasis on the flux of light expressed in lumens rather than on the luminous intensity expressed in candles. But on the other hand, the work "candle" enters into the most commonly used term indicating illumination, namely "foot-candle."

Although there is a relation between the foot-candle illumination and the flux in certain cases, the instrument in question is not a flux meter in any sense, and it would seem desirable to retain the term "foot-candle" as a part of the name of the instrument since I believe that people very quickly come to learn the significance of such special technical terms. We have only to refer to other branches of engineering to see how quickly unusual technical terms are accepted and used, as for example, in connection with the aeroplane and the automobile. In fact, people rather pride themselves on getting new technical names, and I think it is desirable to name this new instrument, which is destined to quite common use, as accurately as possible as a means of educating people to the use of terms which will soon become household terms, as the candle was some time ago. I should certainly not like to see the term "foot-candle" avoided on the ground that the word "candle" is obsolete or obsolescent.

Do you not think, Mr. Sackwitz, that of your two answers to Mr. Hurley's question the second one applies in this case? Though it is true that the instrument would be more sensitive to a given rheostat change, at the same time the candlepower change is less sensitive to changes in current, so that a given rheostat change would make the same difference in the intensity, even though it made a larger difference in the current.

MR. SACKWITZ: Answer to Mr. Cady's question on the rheostat. Our first idea in putting the stop on the rheostat was that

since we wanted it to act as a switch in the off position, we thought the fact that it would sort of click into that position would be something of an indicator that the instrument was thrown out of circuit.

As to the weakening of the spring in the rheostat arm, these instruments have only been in service for a short time, but we have not experienced any trouble and we do not anticipate any, because the stop is so far from the center or turning point of the arm that the slight distance which the arm is caused to rise is not enough to even approach the elastic limit of the spring.

Answer to Mr. Hurley's question. As to the accuracy of the readings obtained with the foot-candle meter, I might say that in calibrating the scale we have used an illumination of 5 foot-candles on the photometer bar, under conditions of fairly good color match; that is, we set up the foot-candle meter on the photometer bar at a point where the scale receives an illumination of 5 foot-candles. We then adjust the voltage of the comparison lamp to such a value as will cause the 5 foot-candle point of the foot-candle meter scale to read correctly. The position of the pointer is then marked on the voltmeter scale. If various other observers used the foot-candle meter with this calibration it seems reasonable to believe that they might get somewhat different results, but due to the fact that it is calibrated with a fairly good color match, if the other observers use it for reading illumination giving a reasonably good color match, I think the limits of accuracy should be, say 15 per cent. Under some conditions better accuracy than this might be obtained.

Answer to Mr. Hurley's question regarding the use of an ammeter instead of a voltmeter. We tried using an ammeter on some of the first models and noted the lack of desirable sensitivity in setting. The increment of change on the scale per unit of change of candlepower of the lamp is only one-half as great in using an ammeter as compared with using a voltmeter.

Another objection to the use of an ammeter was the effect of temperature change on the calibration of the instrument. Most of the ammeters for this purpose are equipped with a shunt which

is made of non-temperature coefficient metal and a moving coil of copper. As a change in temperature affects only the resistance of the copper coil and not the resistance of the shunt, it is obvious that the calibration of the instrument would be different at different temperatures.

Answer to Dr. Hyde's question. The reading when measuring the flux from Mazda C-2 lamps was about 20 foot-candles. One would not expect that these readings would be affected appreciably by the Purkinje effect. We did not, however, take any readings at lower illuminations. As I said in the paper there are many tests of interest that could be performed but which we have not yet had the opportunity of performing.

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ON PREFERRED PROPORTIONS IN COMBINING GENERAL AND LOCALIZED LIGHTING*

BY F. C. CALDWELL AND W. M. HOLMES.

When conditions justify the combined use of localized and general illumination the best proportioning of the light received from each becomes a matter of interest. Such conditions sometimes prevail in office or work-room lighting, but are especially characteristic of the lighting of living-rooms and libraries. Where a high foot-candle intensity on the working plane is obtained entirely by general lighting there is difficulty in avoiding glare from the light source or sources; this is especially true in a small room. On the other hand, the attempt to obtain such an illumination solely from a localized source is likely to produce unpleasant contrast. For any given case there should be some combination of the two forms of illumination that would on the whole, give the greatest satisfaction. The suggestion that this matter be made the subject of a quantitative study is due to Mr. L. B. Marks, to whom the authors wish to make acknowledgement. The solution of the problem involves so many factors that it would probably be impossible to find a ratio which could be universally applied. A step in this direction, however, has been taken by working out one or two definite cases, where the conditions are made simple and are carefully defined. While the results obtained from such an investigation hold only for the assumed conditions, they may serve as an indication of probable requirements for other and more complex cases.

The problem takes the following form. A room of given dimensions and wall characteristics is provided both with general

* A paper prepared for the 1916-1917 Correspondence Convention of the Illuminating Engineering Society. This paper was also presented before the Chicago Section of the Society, November 15, 1917.

lighting and with a given form of localized lighting. While the total intensity on the working plane is kept constant, the relative proportions from the two sources are adjustable by methods explained below, and a series of observers decide upon the proportions of localized and general light which give the greatest satisfaction. Depending on the form of fixtures from which the localized light is supplied, this problem may have several phases. Thus for the general illumination, indirect lighting may be used or a properly designed system of ceiling fixtures, while the localized light may be obtained from a desk or table lamp which may have a translucent or opaque reflector and the light from which may be more or less diffused. Looking next at the problem from the point of view of the room, while the ceiling may be assumed to be white or nearly so, the walls may be light or dark. Also the ceiling may be at different heights. Again, questions of furnishings, pictures and colors may come in. These variations may offer material for future investigations, but in the first attack it seemed best to keep the problem as simple and definite as possible, even at the risk of its not being of the most general application. Thus a room with white ceiling and black cloth walls was chosen, and the direct light was obtained from a table portable with an opaque reflector and an opening so low that the light was not visible to the observer. Also the light was diffused by means of ground glass.

DESCRIPTION OF ROOM AND APPARATUS.

The testing was done in a room 10 ft. 6 in. (4.6 m.) square. The ceiling was adjustable as to height and was used at 9 ft. (2.7 m.). It was constructed of white bleached muslin, stretched over a frame. The walls were covered with a lusterless black calico in one test and with light paper in the other. A table near one side of the room, together with a chair for the observer, comprised the furniture. The general illumination was obtained from lighting units in wall boxes, one on each side of the room. These boxes are 10 in. by 10 in. by 4 ft. (25 cm. by 25 cm. by 122 cm.), are adjustable up and down and, to give the most uniform intensity on the ceiling, were placed 3 ft. 10 in. (1.2 m.) below it. Each of the four boxes contain five lamps ranging from 15 to 100 watts. A show-window type reflector was

used. The lamps were arranged on five circuits, each circuit carrying in parallel the lamps of the same size, in the four boxes.

The localized illumination was obtained from a portable lamp on the table. It consists of a rectangular box lined with white blotting paper, as shown in Fig. 1, and having an under surface of ground glass. The box contains five lamps of wattages ranging from seven and one-half to forty, each lamp on a separate circuit. The ground glass is 10 in. by 14 in. (25.9 cm. by 35.6 cm.) and is 14 in. (35.6 cm.) above the table. In Fig. 1 is shown the location of the table, the observer's chair and the wall boxes. The location of the book which centered the attention of the observer was on the table in front of the lamp as shown by the X in Fig. 1. The observer sits on one side of the room and faces toward the center.

DESCRIPTION OF THE TEST.

The purpose of the test was to determine the proportions of localized and general light that would give the most satisfactory illumination for a person who is reading, but who is also mindful of his surroundings. By "localized" lighting is meant the light from a near-by source that distributes its flux directly upon the working plane; it may be more or less diffused. By "general" lighting is here meant the light from concealed sources which is reflected to the ceiling and which diffuses the light to a marked degree. This lighting was further designed to maintain a fairly uniform degree of brightness over the whole ceiling.

With the two separate systems, it is possible to keep the intensity of illumination on the working plane constant and to obtain any proportions of localized and general light wanted. This was done by changing both the number of lamps used and the voltage on the lamps. The change in color was not noticeable.

The test was arranged in three series for three different intensities or brightness levels. The values of illumination used on the working plane were 2-, 4- and 6-foot-candles respectively. Each series comprised ten transition steps in passing from all general to all localized light. The intensities from the localized and general light sources were separately determined by means of a Macbeth illuminometer. A table was then constructed in which the circuits and voltages required for each step in the series were

tabulated. Each step was numbered, the steps for all general light being No. 1, and that for all localized, No. 10.

One hundred observers passed their judgments upon each series and noted the proportions of localized and general light that suited them best.

The most important of the possible variations of the test was considered to be the use of light walls in place of dark. While the time did not suffice to repeat the whole series of observers for this case, a test covering ten of them was run to ascertain whether any notable difference was observable. The walls were covered with a very light yellow wall paper down to a height of 3 ft. (91 cm.) from the floor.

METHOD OF PROCEDURE.

The observers were taken through the series of tests one at a time. The same explanation and instructions were given to each and were in substance as follows:

We are trying to determine the proportions of general and localized light that will give the best results for living-room conditions. The conditions assumed are that the light affords comfortable reading and at the same time makes the surroundings pleasant. We obtain the general light from the side wall boxes and the localized light from the reading lamp. We start out with all general light and gradually change towards all localized light, keeping the illumination on the booklet constant, and only varying the proportions of the light from the two sources. We want you to pick out the step in the series that suits you best for living room illumination. The changes will be gradual and probably you will not be able to note much change from one step to the next. However, note whether each step is better or worse than the preceding step and use this as a basis for making your decisions. We will pass through the steps rather rapidly, and you need not do any reading, but merely glance at the paper and see whether or not the reading conditions are good, then glance around the room, including the ceiling in your vision, and note the pleasantness of the surroundings.

After a test had been carried through in accordance with these instructions and the observer had indicated his preference, the order of procedure was reversed and the observer again made his selection with a condition of increasing general light. In this way any prejudice due to the direction of change was eliminated. Only four steps were used in this part of the test.

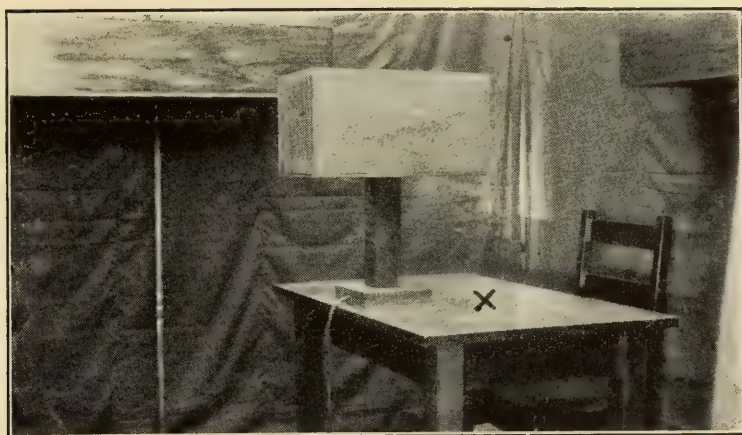


Fig. 1.—Portable lamp.

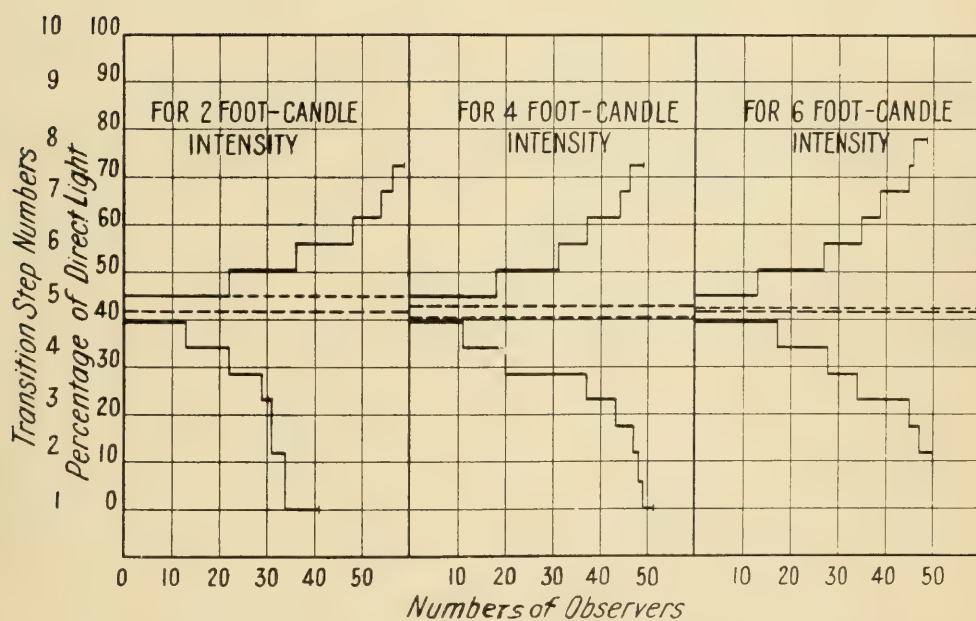


Fig. 2.—Showing, for each foot-candle illumination, the proportion of direct light preferred by each one of the one-hundred observers. The number of divisions in each horizontal line gives the number of observers preferring the corresponding percentage of direct light.

-----Arithmetical mean
 —————Maximum of "probability." Each division of the horizontal lines represents one observer's preference.

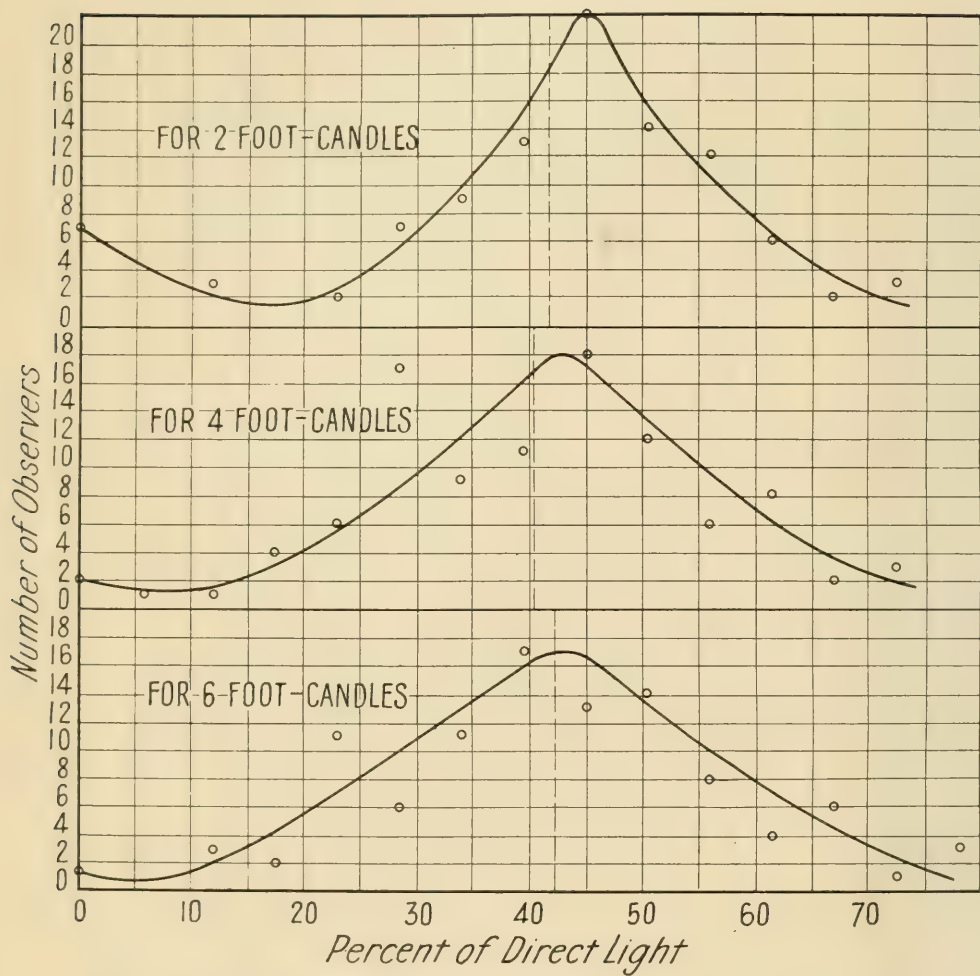


Fig. 3.—Showing the number of observers preferring each percentage of direct light, arranged like a probability curve.

DATA AND RESULTS.

Table I shows the data and computed results for the ten observers who were tried both with the dark and with the light walls. Their cases are given as typical of the data obtained from all of the observers.

Table II shows, for dark walls and for all of the one-hundred persons tested, the number of observers that preferred each given percentage of direct light. The number of men observers for each percentage is also given. These data are shown graphically in the three curves of Fig. 2. In these curves the percentages of the illumination on the working plane, that were obtained from the direct light source, are used as ordinates, while each horizontal line indicates by its length or number of divisions, the number of observers who preferred the corresponding proportion of direct light. The two horizontal lines show the location of the arithmetical mean of the observations and of the maximum points of the curves of Fig. 3 as explained below.

Fig. 3 shows the same data in a somewhat different way; the number of observers preferring each percentage of direct light are here used as ordinates, and a smooth curve plotted. This curve resembles the so-called "probability curve" as used in connection with statistics and errors of observation. The vertical lines show the arithmetical means for the three cases. It is interesting to note that the maxima of these curves come so close to the arithmetical means. While in the case of the regular probability curve its maximum should coincide with the mean value if the number of observers were large enough, it does not appear that this would necessarily hold in the present tests, where a determination of personal opinions rather than of an exact physical quantity is being made. The effect on this point of the seven observers who preferred entire general lighting in the 2-foot-candle case may be noted.

The form of a probability curve is an indication of conditions under which the observations were made. The narrower and steeper the curve, the more favorable the conditions of observation or the more accurate the means of measurement. It is, therefore, interesting to note that the lower the intensity of illumination the steeper does the curve become. Also the points lie

TABLE I.

Observers decision of the best step in the series													
		Number of steps chosen						Average of Decisions					
		2 foot-candle		4 foot-candle		6 foot-candle		Number of step			Per cent. of local illumination		
Serial number of observer	State of wall decorations	local		local		local		2 ft.-candle		4 ft.-candle		6 ft.-candle	
		increased	decreased	increased	decreased	increased	decreased	increased	decreased	ft.-candle	ft.-candle	ft.-candle	ft.-candle
3	dark	3	5	5	6	5	6	6	4.0	5.5	34	50	50
3	light	5	6	4	5	5	6	6	5.0	4.5	45	39	50
5	dark	7	5	5	6	7	7	7	6.5	5.5	61	50	67
5	light	3	4	4	4	5	4	5	3.0	4.0	23	34	45
7	dark	4	5	4	5	4	5	5	4.5	4.5	39	39	39
7	light	3	4	3	5	4	5	5	3.5	4.5	28	34	39
9	dark	5	5	4	4	3	3	3	5.0	4.0	45	34	23
9	light	3	3	3	4	3	3	3	3.0	3.0	23	23	23
10	dark	7	7	6	7	7	7	7	7.0	6.5	67	61	67
10	light	4	4	6	6	7	6	6	4.5	6.0	39	56	61
12	dark	4	5	6	6	5	6	5	4.5	6.0	39	56	45
12	light	7	7	4	5	4	4	4	7.0	4.5	67	39	34
14	dark	3	4	2	3	2	4	4	3.5	2.5	28	17	23
14	light	4	5	6	6	7	6	6	4.5	6.0	39	56	61
15	dark	4	4	4	5	5	5	5	4.5	4.5	39	39	45
15	light	5	5	5	6	5	6	6	5.0	5.5	45	50	50
51	dark	6	6	4	6	4	6	6	6.0	5.0	56	45	45
51	light	6	6	5	6	7	7	7	5.0	5.5	45	60	67
97	dark	5	5	4	4	3	4	3	5.0	4.0	45	34	23
97	light	7	5	5	5	2	5	2	7.0	5.0	67	45	12

Table I.—Shows the data and computed results for the ten observers who were tried both with the dark and with the light walls.

better on the curve for the lower intensity. This difference could not have been due to longer experience, as the 2-foot-candle test was made first and was followed immediately by the others.

TABLE II.—NUMBER OF OBSERVERS CHOOSING EACH PERCENTAGE OF DIRECT ILLUMINATION. FOR DARK WALLS AND FOR ALL OF THE 100 OBSERVERS.

Percentage of local illumination		Number of observers					
		² foot-candle		⁴ foot-candle		⁶ foot-candle	
		Total	Men	Total	Men	Total	Men
0%		7	3	2	1	1	0
6		0	0	1	1	0	0
12		3	3	1	0	3	2
17½		0	0	4	2	2	2
23		2	1	6	6	11	9
28½		7	5	17	13	6	6
34		9	6	9	7	11	5
39½		13	9	11	7	17	13
45		22	9	18	14	13	9
50½		14	8	12	8	14	10
56		12	10	6	5	8	6
61½		6	3	8	2	4	1
67		2	2	2	1	6	4
72½		3	2	3	3	1	1
78		0	0	0	0	3	3

TABLE III.—SUMMARY OF RESULTS FOR 100 OBSERVERS ON DARK WALLS.

Illumination on the working plane in foot-candles	Arithmetical mean of decisions as to preferred per cent. of local illumination		Maximum of "Probability" curve	Percent. of observers preferring given intensity
	For all observers	For men observers	For all observers	
2	41.9%	43.4%	45%	15%
4	40.5	40.2	43	56
6	42.3	42.3	42	29
Average	41.6	42.0	43.3	

Table III gives the mean values of the observations for the different cases and likewise the maximum points of the "prob-

ability" curves. Here also are given the preferences of the observer for the different intensities of illumination used. These last data, while not related to the principal investigation were obtained incidentally. This table shows that there is no important difference between the preferences of the men and women tested.

Table IV gives the brightness of the two-light sources, namely the ceiling and the diffusing glass of the portable corresponding to each foot-candle intensity on the working plane. Of these the

TABLE IV.—BRIGHTNESS OF LIGHT-SOURCES FOR THE PREFERRED PROPORTIONS OF DIRECT AND INDIRECT LIGHT.

Foot-candles on working plane	Apparent foot-candles		Candle power per sq. ft.		Millilamberts		Ratio of ceiling foot-candles to foot-candles on working plane
	Portable	Ceiling	Portable	Ceiling	Portable	Ceiling	
2	27.0	5.8	8.6	1.8	29	6.1	2.9
4	46.0	10.6	14.6	3.4	49.3	11.5	2.6
6	65.0	14.9	20.6	4.7	69.3	15.8	2.5

former is much the more important, and the approximate constancy of the ratio of its brightness to that on the working surface is interesting. Whether the decrease in this ratio with increase of intensity on the working plane is significant or not there is probably not enough data to determine, but it seems not unlikely that such a decrease would exist.

While some idea of the agreement between the preferred percentage of particular individuals corresponding to the different foot-candle intensities may be obtained from the data of Table I, the curves of Fig. 4 give information on this point for the whole group of one hundred. The ordinates of curve "A" give differences in percentage between the 4-foot-candle and the 2-foot-candle preferences, while those of curve "B" give differences between the 6-foot-candle and the 4-foot-candle preferences. As in Fig. 2, the horizontal portions give the numbers of observers showing each difference. Thus from curve A, there were eighteen observers who preferred the same percentage of direct light for both the 2- and the 4-foot-candle intensities and thirteen who wanted $5\frac{1}{2}$ per cent. more direct light in the 4-foot-candle

test than in the 2-foot-candle one, but only ten who wanted $5\frac{1}{2}$ per cent. less. It will be noted from these curves that 75 per cent. of the observers came within a difference of 11 per cent. plus or

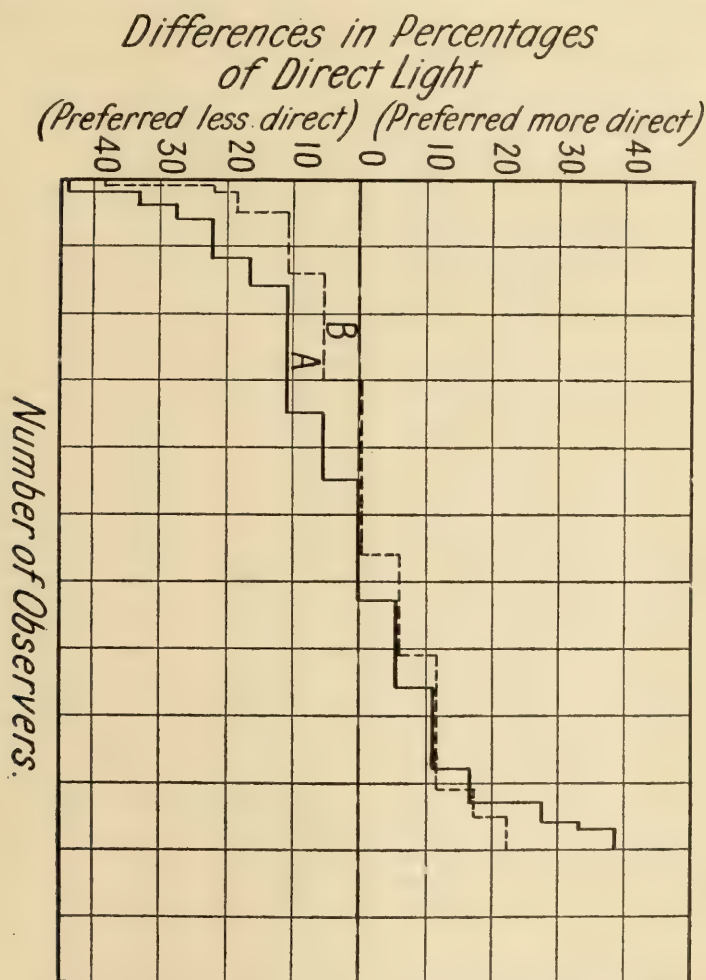


Fig. 4.—Showing differences between percentages of direct light preferred by each observer for the different foot-candle intensities. The length of each horizontal portion gives the number of observers having the corresponding difference between their preferred percentages.

Each horizontal division represents 10 observers choosing the same difference in percentage of local light.

Curve A—for 4 and 2 foot-candles.

Curve B—for 6 and 4 foot-candles.

minus, between their preferences for the 4- and 2-foot-candle cases and 83 per cent. for the cases of 6- and 4-foot-candle; in this latter case also, 26 per cent. called for the same per cent. of direct light for both intensities.

Table V gives the results of the brief preliminary test on the effect of changing the color of the walls from dark to light. The

results of this test make it very probable that on the average the color of the walls makes no important difference in the preferred proportions of localized and general lighting. What differences, if any, might result from changes in arrangements, furnishings, size of room, or other conditions were not investigated.

TABLE V.—PRELIMINARY TEST WITH TEN OBSERVERS USING BOTH DARK AND LIGHT WALLS.

Foot-candles on working plane	Mean for 100 observers with dark walls from Table IV.	Preferred per cent. of local light	
		Mean of ten observers	
		Dark walls	Light walls
2	41.9	45.5	42.2
4	40.5	42.8	42.3
6	42.3	43.3	44.4
Average	41.6	43.9	43.3

SUMMARY.

The conditions of the test were as follows: The test took place in a small room with a white ceiling and very simple dark colored furnishing. The general lighting was obtained entirely by reflection. The localized lighting was from a table lamp with opaque reflector and diffusing glass. One hundred observers expressed their preference upon which and for the conditions described, the following conclusions are drawn.

1. With light ceiling and dark walls and throughout a range of foot-candle intensities on the work from two to six, about 40 per cent. of localized and 60 per cent. of general lighting is preferred.

2. Within the above range, this ratio is not materially affected by the intensity of illumination upon the working plane.

3. This ratio is approximately the same for men and women.

4. Changing the walls to a light color does not greatly affect this ratio.

5. For the above preferred proportions of direct and indirect light and with dark walls, the ratio of the brightness of the ceiling to that on the working plane lies between $2\frac{1}{2}$ and 3.

DISCUSSIONS.

A. H. MUNSELL: A closely allied problem needs the same careful attention, one that has occupied my attention for several years. Assuming that the proportions of a localized and general lighting have been well established for lighting a certain page of type; and that this meets the conditions of the library, there still remains the question of lighting any pictures that may have been hung from the walls of that room; and for which these proportions are not happy. Since pictures have been produced in studio daylight, they will appear to best advantage if something approximating that light can be produced artificially. The three factors being:

- (1) Quantity of light.
- (2) Color of light.
- (3) Direction of light.

Failure in any of these qualities will bring a less favorable emphasis to bear upon the "chromatic composition" of the painting; and since pictures are hung from the walls to bring pleasure to us and to our friends, they will fail in that function in proportion as they miss the conditions of studio daylight.

If appropriate at this time, I wish the question might be raised of having two forms of artificial illumination for the library. The first is already defined by this paper; and a second is such as will bring out the best qualities of paintings produced in studio daylight. Those with large collections of painting are very apt to build a special gallery with a special light; but by far the majority of us who own paintings must place them upon the walls of our homes and encounter this difficult problem, which is not solved by the conditions of a good reading light.

F. C. CALDWELL: In reference to the remarks of Mr. Munsell, the new daylight incandescent lamps would seem to solve the color problem in the case of paintings, in a very satisfactory way. These lamps are already being used for living-room illumination with excellent results. The providing of local lighting for paintings has the objection, especially in private libraries, that the lighting fixtures are likely to be unpleasantly conspicuous if the light is placed far enough from the painting to give satisfactory

results. If such local illumination is to be used, however, the method adopted in our paper could probably be applied, though it is doubtful whether as consistent results would be obtained as were found in our tests.

O. L. JOHNSON: Professor Caldwell's paper certainly shows a step forward in investigation of illumination problems. I am sorry that he has not gone further and made some tests on the preferred proportions, as it applies to factory lighting. It would be interesting to know what effect might be obtained, on both horizontal and vertical surface, when bare lamps are used for local lighting as they are in a great many places.

I agree heartily with the statement, that a pleased workman means more output, but I am not convinced that the pleased or cheerful workman is always one who has the localized lighting. I am a strong believer in General Illumination for factory purposes. Localized lighting in machine shops, for instance, should not be allowed. The more cheerful workman is certainly going to be the better workman, because he can properly see his work, and I believe it is possible for the system of general illumination, to be so designed, that the operator will be much more pleased and much more cheerful, because of the much more pleasant appearance of the room. I am certain that if a man has a bright light in front of him and turns to walk away from his work, stumbling over a box or other construction, thus hurting himself, that he is not going to be a very cheerful worker, and his output is certainly going to be curtailed.

The system of lighting which enables operators to see their work at the same time provides sufficient illumination, so that he might also see any construction that might be in the aisles, thus avoiding a great many accidents.

I sincerely believe a system of general illumination is the proper one, both from the standpoint of the employer and the employee.

J. R. CRAVATH: The localized lighting as described by Professor Caldwell here with its diffusing glass between the source and the page, was, as has been pointed out, quite different from what we have in practice in a great majority of cases. That is the localized lighting was practically localized diffused lighting.

In reading on any ordinary paper or working on polished metal in industrial plants one might expect that this kind of localized diffused light might be much more satisfactory than the kind we ordinarily get.

I have been considerably interested in noticing the instructions given here to the observers, as indicating the exact conditions under which the test was made. I take it if the instructions were carried out not a great deal of attention was given to the actual lighting conditions, for continuous work but more to the general effect.

The results here shown are very interesting and valuable because they show quite decisively what the majority opinion is on this question of relative proportions of general and localized lighting based on general impressions. The majority evidently have tastes somewhere between certain artists and architects who are strong on localized light for living rooms and those who want nothing but general lighting.

F. C. CALDWELL: Referring to Mr. Johnson's remarks, we hope to carry the tests further, for, as indicated in the paper, we have only scratched the surface of the problem. We are particularly well fixed for this kind of test. There are not many places, except in a college, where you can call in so many people and get them to put a half-hour on a test of this sort. Some kind of a direct or semi-indirect fixture in place of the total indirect would be one of the next things which should be taken up.

In regard to factory lighting, for ordinary intensities, say up to 6 or 8 foot-candles, the best results will usually be obtained from general illumination. There are special cases where bench work even for these intensities can well be supplied with local light. For extra high intensities, say 15 to 20 foot-candles, or above, we usually have to depend upon local illumination for a part of the light. The kind of lighting that Mr. Johnson mentioned with bare lamps in the face of the workmen, we can all condemn without qualification.

Answering Mr. Cravath; the idea was distinctly the obtaining of the most comfortable and satisfactory rather than the least fatiguing reading conditions. To have based the results on the

least fatiguing reading conditions would have taken very much more time.

With regard to specular reflection from the paper, it would seem very difficult to specify a specular reflection for the purposes of the test, and furthermore, illumination which would give such reflection could not be considered as representing good practice. Even with bare filaments, it is usually possible to so locate the lamp relatively to the work that specular reflection is negligible.

With regard to the form of the portable; here again the effort was to get conditions which could be definitely specified and reproduced. If the portable used were of a dark shade of colored glass, the results would probably be practically the same as with the opaque reflector. A highly translucent glass reflector would doubtless give very different effects. In the beginning of the paper I mentioned the fact that the subject was suggested by Mr. L. B. Marks; as I recall the case he mentioned in connection with the problem was one that he had designed where high intensity was called for by bookkeepers in a bank. He obtained it by the use of combined ceiling lighting and local lighting, the latter obtained by a special fixture with an opaque reflector placed in front of the bookkeepers so that no light from the fixture directly reached their eyes. In other words that particular case was practically the same thing as we had; one would also get the same effect from many portable fixtures.

G. H. STICKNEY: Before discussing the subject matter, I would like to compliment the authors on their broad-minded attitude toward their investigation. Their warning as to the danger of generalization is in contrast to a marked tendency among investigators to draw sweeping conclusions from particular data.

Taking up the test itself—it would appear that the judgment of an observer was based partly upon the appearance of the printed page and partly upon the general effect—but that there was no indication as to the weight which was placed upon each factor. It would seem to me that the results would be still more valuable if these two elements were differentiated and also if the test included actual serious reading. The time and

expense necessary for securing such additional data may have rendered such a course prohibitive.

Since the intensity on the test sheet was maintained constant for the various steps from local to general illumination, it would necessarily follow that the amount of light in all other parts of the room would increase with the percentage of general illumination. In so far as judgments were based upon the general effect in the room, it would seem to me that this would tend to favor the general illumination, while it might react slightly in the other direction as regards reading value.

In this connection I am merely raising a question, which emphasizes my thought as to the desirability of more data to permit a segregation of the criteria.

Have the authors given any consideration to the effect of variation in the characteristics or location of the local lamp? Can they say whether or not such variation would have any marked effect on their results?

I am a little surprised not to find an indication in favor of localized lighting in the dark-walled room and a corresponding tendency in favor of general lighting in the light-finished room. While I have made no laboratory tests along this line, my observation and experience in practical lighting have seemed to agree with the conclusion that for the most pleasing effect, light-finished rooms require relatively high illumination on the walls, while dark-finished rooms should have a relatively low wall illumination.

The test in general seems to be a very practicable one, and it is to be hoped that these other experimenters will carry on similar investigations on other factors and from all viewpoints.

I want to congratulate the authors on the way they have presented this question. After several years experience as Chairman of your Committee on Papers in the Society I began to think that every time a man made a test of a particular condition he wanted to generalize from it. I find here that the authors in their introduction called attention to the danger of generalizing from the result. As I understand the test, they really used two criteria; that is, glancing at a piece of printed matter and then glancing around the room. They did

not do serious reading. They just simply glanced at something and then they glanced around the room. Now, I am wondering how much of each of those elements influenced choice. Undoubtedly, it is quite different with different observers, but I have been wondering if it might not be interesting to separate those two and perhaps introduce the third, of reading for a period. Of course, I realize that involves considerable of an effort. Now, there is one other thought that occurred to me. Supposing we consider particularly the criterion of glancing around the room to see how pleasant it was. Now, as I understand it, the intensity was held constant on the reading matter. Then, as you go from local to general light, the general level of illumination in the room advances; that is, in order to maintain the constant intensity on the table in going from one condition of light into the other, the general intensity in the room must be elevated a good deal. I do not know what it means. I do not know quite how to interpret what they would do. If they are judging it from the back of the room, a person who likes a brightly lighted room would be rather inclined to favor the general illumination and I am not sure but the person who was—if a person was forming a judgment based on the reading, on serious reading, would have been inclined to have gone a little further towards the local because it extended over a period of time it was quite possible more eye rest might have been obtained with the low general illumination when glancing up from the paper. I am not advancing any particular theory on it. I am only raising the question and asking. I would like to ask the authors if they have any interpretation to put on that. Then, I am wondering whether a different location of the table lamp—I think the author used the most common location of the table lamp and yet if I were selecting the most desirable to read, I think I would have made sure that there could not possibly have been a direct surface reflection from the paper. Now, I am not questioning that they have done well in selecting that location, but I am wondering if the result might not have been possibly different with a different location of the material to be read.

Now, I have never made any observations on the laboratory basis on this sort of thing, but I have made a great many observations of the lighting of living rooms, and have drawn a

general conclusion that in a high-wall room we would like to have considerable light on the walls for esthetic reasons; that is, to make the room itself as a whole appear pleasant. If we are called upon to light a dark-wall room in a den, I have always thought of the different things. Then I like to keep the light off the walls and off the ceiling, and make what you call a cozy effect. It always seemed more pleasant for the dark walls not to have much light on the walls. I do not know why it is, but I think the experience of those who have been working on actual installations do find that, and I am rather surprised that the results do not show something more in favor of the localized lighting in dark rooms, and of general lighting in light-wall rooms.

WARD HARRISON: In judging illumination intensities we are accustomed to consider errors of 5 or 10 per cent. as relatively small. This fact lends double significance to the selection of between 41 and 45 per cent. by the maximum number of observers in these tests as representing the most satisfactory proportions of localized and general lighting. At the same time from the standpoint of practical application the result can scarcely be termed a "happy" one. If 90 per cent. local and 10 per cent. general lighting were most desired, the choice would at least have the merit of saving some current or if, on the other hand, all general lighting were selected the necessity for using individual lamps with their attendant inconvenience, installation expense, and maintenance would be eliminated. Actually the preferred proportions are such that if followed out the saving in energy consumption over an entirely general system would be nil and at the same time the full equipment of local lamps would have to be provided. Prof. Caldwell pointed out that as the general brightness level was raised in these tests the curves become less steep, that is the preference for any particular proportion of local lighting was somewhat less marked. It would be interesting to determine whether if an intensity of 50 foot-candles were used as the basis, the preference for 40 per cent. local lighting would still persist or whether under these conditions the observer would cease to care where the light came from. To put the matter another way, do not these tests, calling as they do for a

preponderance of general illumination, permit us to regard the desire for a local lamp as a physiological factor which comes into evidence at those brightness levels which we are accustomed to associate with artificial illumination and which would disappear under daylight conditions?

W. R. MOTT: I think that this is a splendid paper. Of special interest to me, is the increasing importance of all diffused general lighting at decreasing intensities. At very low intensities as in the dark photographic rooms of the Eastman Kodak Co., all indirect (red) lighting (arranged by Dr. Meas) has been found the best. (The glare danger, and discomfort with local lighting is most serious at the low intensities necessary in working with sensitive photographic paper.) The same advantage of indirect lighting at low intensities is shown in the beautifully lighted tunnel entering Nela Park.

The reason for the special value of 40 per cent. local to 60 per cent. general diffused lighting may lie in an unusual power of perceiving useful and pleasing shadows in these proportions. All such effects are practically lost with diffused general lighting without some material local lighting. (All local lighting gives harsh black shadows. The happy medium is a suitable combination giving pleasing helpful luminous shadows so well understood by photographers.)

P. W. COBB: The paper has been very interesting to me. The illuminating world, ever since I entered it, has been in search of a valid criterion by which an illuminating system could be judged. We have several tentative criteria. For example, in the work now under discussion the visibility of objects in the working plane might have been investigated. The results so obtained would not, however, give us any clue as to what the hygienic effect of that particular light-distribution would be, no idea of what degree of fatigue might follow its prolonged use.

If we seek information upon this point, we are driven to measure visibility, in one of its phases, under the different test conditions; or we may do as the authors have done, and let the subject sit or work under the various conditions and indicate his preference. Such a preference, however, might be based upon

the degree of comfort or discomfort immediately experienced or anticipated; or it might be based on the subject's estimate of the esthetic value of the various distributions—simply a decision as to which is the most pleasing to him in view of his individual taste, experience and education.

I was interested to notice that the old law, Weber's law, crops out in this work where it seems to apply as well as in the case of earlier and more exact researches in sense-physiology. Weber's law states that the least noticeable increase of a stimulus is a constant fraction of that stimulus. In other words, the error in estimating equality, as is well known in photometry, is not a constant error, but it is a constant fraction of the quantities equated. If we enlarge upon this a little, it leads to the conclusion that as far as vision is concerned (or the other senses, for that matter) it is proportionately of the stimuli rather than their absolute value which is mainly concerned. With the same distribution of light, a room looks much the same in spite of wide differences in the total flux of light, just as a piece of music sounds the same at different distances from the piano.

I notice in the work under discussion that in general the preferred condition is that in which the illumination upon the reading surface bears a constant ratio to the general illumination, independent of the absolute values of these. Of course, in drawing such a conclusion we cannot compare conditions involving light walls with those involving dark walls, for two reasons. First, that under equal illumination the stimulus value of the latter (their brightness) is lower, and the physiological result is different, and second (and more important) the change probably brings about a complete alteration in the esthetic value of the combination, upon which the results no doubt largely depend.

F. C. CALDWELL: Replying to Mr. Stickney, Dr. Cobb's statement of the matter represents the conditions pretty closely; that is, it was really an esthetic judgment that we sought. The test was not long enough to bring in the element of fatigue at all. In other words, we asked the observer which illumination they liked best; which was the most pleasant for them.

As to whether we should have obtained any different result if the light had been at one side instead of in front, that is a mat-

ter which might well be investigated. I doubt if we should get a difference that would be of any importance. We were careful to select paper which had no appreciable glare.

With regard to the use of very high intensities, we have no further data upon it. I should suppose that with very high intensities the tendency would be to prefer more of the light from a local source; and not to have the ceiling so brilliantly lighted.

As regards the question of the application of the results, there are certainly many cases where the working conditions would favor entire general illumination. For instance, in the case of mill or factory lighting, except perhaps where very high intensities are necessary, general illumination is certainly to be preferred from the practical point of view. On the other hand, for the cases for which this paper was prepared, for example the case of the living room, there would not be the same objections to combined lighting. At the Chicago section the other day one of the audience expressed his surprise at the fact that we got the same results from men and women. His experience had been that the women were in general much more favorable to general illumination than the men.

AN INTEGRATING HEMISPHERE.*

BY F. A. BENFORD, JR.

Synopsis: During the work of developing the compensating screen described in a previous paper, the calibration of the instrument required the use of only one of the hemispherical halves of the integrating sphere. This suggested the permanent use of a hemisphere such as is described in this paper. The sphere is well established as a photometric instrument and the theories of the two instruments are compared to show that the hemisphere has certain theoretical advantages, and the tests that have been completed confirm the calculated data.

It was found necessary to correct for the lack of pure diffusion by the sphere paint and the means of making this correction is described along with the absorption effects of the test unit in both sphere and hemisphere.

PURPOSE OF INVESTIGATION.

There are theoretical grounds for believing that a hemisphere with a white diffusing inner surface may be used for a wide range of photometric work. It is the purpose of this investigation to examine the theory of the hemisphere in comparison with the theory of the integrating sphere, now so widely used, and to include some laboratory test data on the relative merits of the two instruments. As is well known, the integrating sphere does not give reliable data when the test unit is relatively large in comparison with the sphere, or when the unit has a large light absorbing capacity. Thus, no dependance could be placed upon photometric measurements on a 20 centimeter metal reflector, green on the outside, when photometered in a 1-meter sphere. A great many commercial units are larger than this, and it is necessary to use a 2-meter sphere for their measurement, and even with this large instrument there is considerable chance of integration errors.

* A paper prepared for the 1916-17 Correspondence Convention of the Illuminating Engineering Society.

PROPOSED USES OF HEMISPHERE.

The theories of the two instruments indicate that a 1-meter hemisphere, equipped with the compensating screen described in a previous paper¹ has an advantage in accuracy over the 2-meter sphere with the usual three-screen arrangement, and there is further the great possibility of photometering a projecting unit such as an arc searchlight, a flood lighter, or a spot light. This will be recognized as a departure from the usual integration where the test unit is actually within the instrument and there is always an "absorption factor" that is not taken care of by the compensating screen, and there seems to be no possibility of totally eliminating it in the complete sphere.

CLASSIFICATION OF LIGHTING UNITS.

All lighting units may be roughly divided into two groups, distributing and projecting. There is no sharp dividing line between the two, and often the particular use to which the unit is put must determine its classification. The photometry of these two types is carried out in different manners by the hemisphere and the details of the two methods call for separate investigation.

THEORETICAL JUSTIFICATION.

The work so far done on the hemisphere has as its justification the theoretical performance of the two integrators, and for this reason the two theories are gone into rather fully in connection with the experimental data. The theory of the hemisphere is attacked by a "step by step" method that has proven useful in many ways. The test data included in the latter part of the report show to what extent the mathematical deductions are upheld.

IDEAL SPHERE.

Before attempting to form the equations of the integrating sphere it is customary to assume certain ideal conditions. This simplified the mathematical work and leads to really useful results, providing that these assumptions are not forgotten when the

¹ Benford, Frank A., Jr. The integrating sphere and a new type of compensating screen. TRANS. I. E. S., Vol. IX, 1916, p. 997.

theory is put to practical use. The theory of the hemisphere is limited by identical simplifications, and thus a comparison between the two is fair to both.

PAINT CHARACTERISTICS.

The paint used on the photometric surface of the sphere should be a perfect diffuser. Such a surface would appear equally bright in all directions, and the direction of incident light would have no effect on its brightness, providing the illumination is kept constant. This degree of diffusion is not attainable, and the slight specular action of the sphere paint leads to some interesting results. The brightness of a diffusing surface decreases when viewed near the grazing angle and we might expect that the portions of the sphere near the observing window would appear less bright. Tests have shown that the brightness is very close to uniform when the initial illumination is equal at all points and comes from a source at the exact center of the sphere. The explanation of this is found in the fact that at low angles of incidence the paint becomes more specular in its action and its coefficient of reflection rises. There is thus a tendency for light that has once been reflected at near grazing incidence to keep at this angle in all the following reflections. The slightly increased coefficient at the high angles also assists in increasing the brightness near the observing window. Paint that shows a decrease of 15 per cent. in brightness near the grazing angle under normal illumination will be equally bright at all angles when illuminated by the multiple reflections within a sphere. For practical purposes the sphere paint may then be said to be a perfect diffuser after the first reflection. It will be shown later that in the hemisphere this self-correcting action does not take place to such a complete extent, and some correcting device becomes a necessity.

FOREIGN BODIES.

The usual spherical test methods call for five foreign bodies within the sphere. There are the standard lamp, the test unit, a large screen for the test unit, a medium sized screen for the standard lamp, and a small screen between the two light sources. The amount of light absorbed by each body depends upon its area, its coefficient of absorption and its illumination. The illum-

ination, outside of direct light from the two lamps, depends upon the distribution of brightness on the sphere walls and the relative position of the body with respect to the areas of high and low brightness. There is also interception and reflection of light between the five bodies, and the calculation of the true absorption of the foreign bodies is entirely beyond ordinary mathematical methods. This is the reason for assuming a uniform illumination and brightness over the entire surface of the sphere and for neglecting the interaction of light between the units.

SYMBOLS.

- Let S be the area of the sphere, in square centimeters.
- Let A be the area of the foreign body in square centimeters.
- Let K be the coefficient of reflection of the sphere surface.
- Let a_1 be the coefficient of absorption of the foreign body.

EFFECT OF LIGHT SOURCE ON BRIGHTNESS.

The light source cannot be said to absorb any direct light, and the brightness of a sphere containing a source giving F lumens and having an area A and a coefficient of absorption a_1 is

$$B = \frac{K}{S} \frac{F}{1 - K \left(1 - \frac{Aa_1}{S} \right)} \text{ lamberts} \dots\dots\dots (1)$$

When the light source is very small the brightness becomes practically that of an empty sphere, or

$$B = \frac{K}{S} \frac{F}{1 - K} \text{ lamberts} \dots\dots\dots (2)$$

By combining the two equations the effect of the light absorbing body on the brightness of the sphere can be determined.

$$R_s = \frac{1 - K}{1 - K \left(1 - \frac{Aa_1}{S} \right)} \text{ numeric} \dots\dots\dots (3)$$

The value of R_s are plotted in Fig. 1 for various values of A and a_1 . It is ordinarily not good practice to photometer a unit that is large enough to cause as large absorptions as are plotted. The relation between R_s and the probable error is not a simple one and it is influenced by factors not mentioned or considered here. As a rule, however the size of the probable error will be

proportioned to R_s and it is later demonstrated both by calculation and test that R_s for the hemisphere is only a fraction of the values of R_s for the sphere, and greater accuracy may be expected from the former instrument. There is one peculiar feature that shows the futility of doing more than generalizing on the theory of the

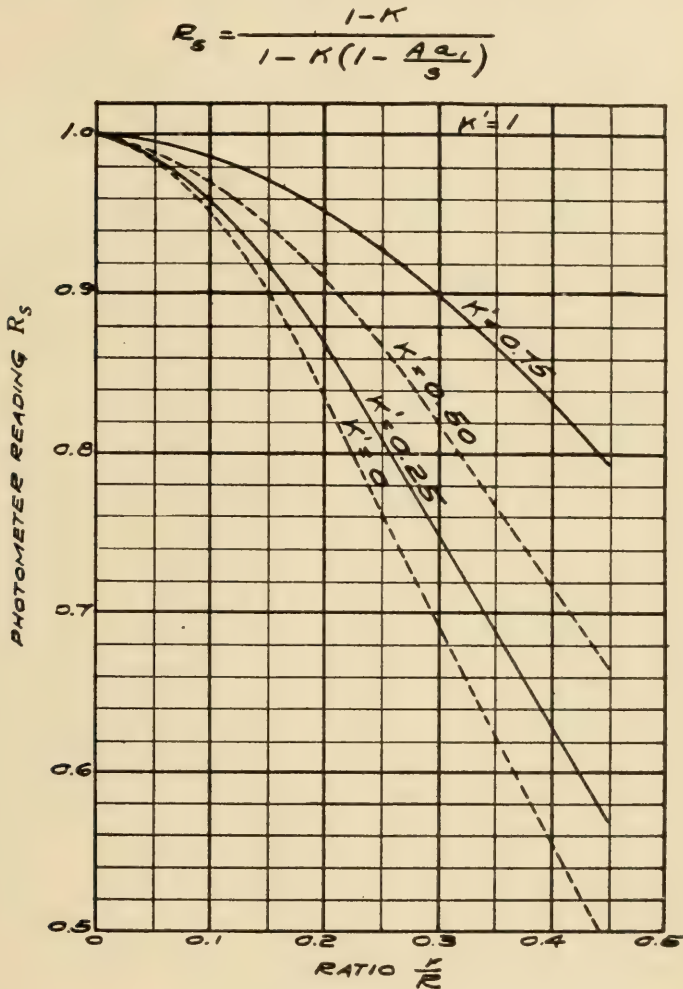


Fig. 1.

sphere. The theory as outlined shows no reason why the accuracy should be effected by the size of the unit. Experience teaches different, and seems to point to the accuracy varying as the area of the instrument and the area is directly related to the values of R_s .

ACCURACY AND COEFFICIENT OF REFLECTION.

Direct comparisons of this nature may only be made between spheres having the same coefficients of reflection. The percentage

decrease is greater when the sphere surface has a high coefficient than when it has a low coefficient, but there are other things to be considered that make it seem probable that the higher coefficient of reflection will always give the best results. The greatest source of trouble in spherical photometry arises from variations in illumination in different parts of the sphere. The reflected light tends to wash out all variations and make the illumination equal in all parts. The amount of reflected light increases very rapidly with the increase of coefficient and for this reason, a high coefficient is to be preferred.

LIMITING CONDITIONS TO SPHERE.

The history of the integrating sphere shows that that instrument has been constantly increasing in size from the date of its invention. This growth is a direct result of the higher accuracy now demanded in all photometry, and the testing of units of a more complicated nature. The test unit must be accepted as it stands and the only way of decreasing the relative size of the unit is to increase the size of the sphere. Spheres 2 meters or more in diameter, are getting to be fairly common but even with these instruments that are reaching the limit of accommodation in an ordinary room, it is not possible to photometer some commercial units with certainty. There are common lighting devices, such as spot lights, searchlights, headlights, and projection equipment in general, that are entirely outside of the sphere's field of usefulness. The question is, how can the light from the test unit be included within the integrating instrument, and the unit itself, with its disturbing action, be excluded? The practical answer to this is believed to be found in the integrating hemisphere.

HISTORY OF HEMISPHERE.

It should be noted that this is not the first attempt to use a hemisphere in spherical photometry. The hemisphere has been used to determine the lower hemispherical flux from arc lamps. The hemisphere when used for this purpose is mounted with its opening upward, and the lamp is lowered into the hemisphere until the light center is in the plane of the opening. This form of integrator has not come into general use, probably because there are two inherent sources of error that have not been overcome in existing hemispherical photometers.

SOURCES OF ERROR.

The first source of error lies in the practical impossibility of determining where the "light center" of some units is located. A simple arc without globe or reflector has a fairly well defined lighter center, and the angular position of the equator, or 90° circle, may be accurately estimated. Such a source may be placed so that the arc lies in the plane of the opening of the hemisphere, and there is small room for doubt that only the true "lower hemispherical flux" enters the instrument. However, if the arc is equipped with a reflector it becomes very difficult to fix upon the new light center. All that can be said with any degree of certainty is that the light center of the combined arc and reflector is between the two. In distribution photometry this difficulty is largely overcome by working at a radius of perhaps 6 meters, but a 6-meter radius hemisphere is out of the question and the error in locating the light equator must be accepted as unavoidable. Needless to say, the present hemisphere with its half meter radius, offers no solution of this difficulty.

The second cause of error in the hemispherical integrator arises from the lack of pure diffusion by the sphere paint, and the lack of uniform transmission at the reading window. The combined effect of these two phenomena is to give the zones at the rim of the hemisphere a higher constant than the zones nearer the window. As a result, the same amount of light in different parts of the hemisphere will give different photometer readings. This makes the constant of the hemisphere vary for different light distributions, which is obviously an unsatisfactory condition. The compensating screen used in this experimental work is especially designed to eliminate this source of trouble. By making all parts of the hemisphere equally effective in getting light to the photometer field it renders the hemisphere, or sphere, in which it is used, almost totally independent of the distribution of light from the source being measured.

PRESENT HEMISPHERE.

The present hemisphere is set with the plane of its opening in a vertical position, and the reading window is at the center or point farthest removed from the opening. The compensating screen is placed in front of the window as shown in Fig. 2. The

test and comparison lamps are held so that their axes of suspension (the rods holding the sockets) are exactly in the plane of the opening. It is essential that this be so, but the axis of the lamp itself may point in any direction whatever without altering the photometric results. This feature is very useful, as it makes it practicable to photometer side lighting reflectors and other asymmetrical units. The methods of test will be discussed later in connection with tests on various types of reflectors.

DEPARTURE FROM IDEAL CONDITION.

It might seem at first thought that there would be very little real difference between the optical phenomena of the sphere and the hemisphere. This supposition would be fairly near the truth if the various ideal conditions of both instruments were fulfilled, but such is not the case. The points wherein the theoretical and actual instruments differ must be investigated in detail to appreciate how far conditions depart from the ideal.

PROPORTIONS OF DIRECT AND REFLECTED LIGHT.

It was noted in a previous paragraph that the sphere paint corrects in part for its lack of perfect diffusion. The precise manner of diffusion on the first reflection was not of extreme importance, because the amount of well diffused light reflected on the 2nd, 3rd, —nth reflections was so much greater. In the case of the hemisphere the amount of reflected light is always less than the initial flux. At each reflection half of the light escapes from the hemisphere, and even if the reflecting surface has the greatest known coefficient, 0.931, the total illumination is

$$E = \frac{I}{R^2 \left(1 - \frac{0.931}{2} \right)} = 1.87 \frac{I}{R^2} \text{ phots.} \dots \dots (4)$$

of which $E_0 = \frac{I}{R^2}$ or over 53 per cent. is due to direct light alone.

The ratio of reflected light to direct light for the sphere and hemisphere are tabulated below for steps of 0.1 in the coefficient of reflection.

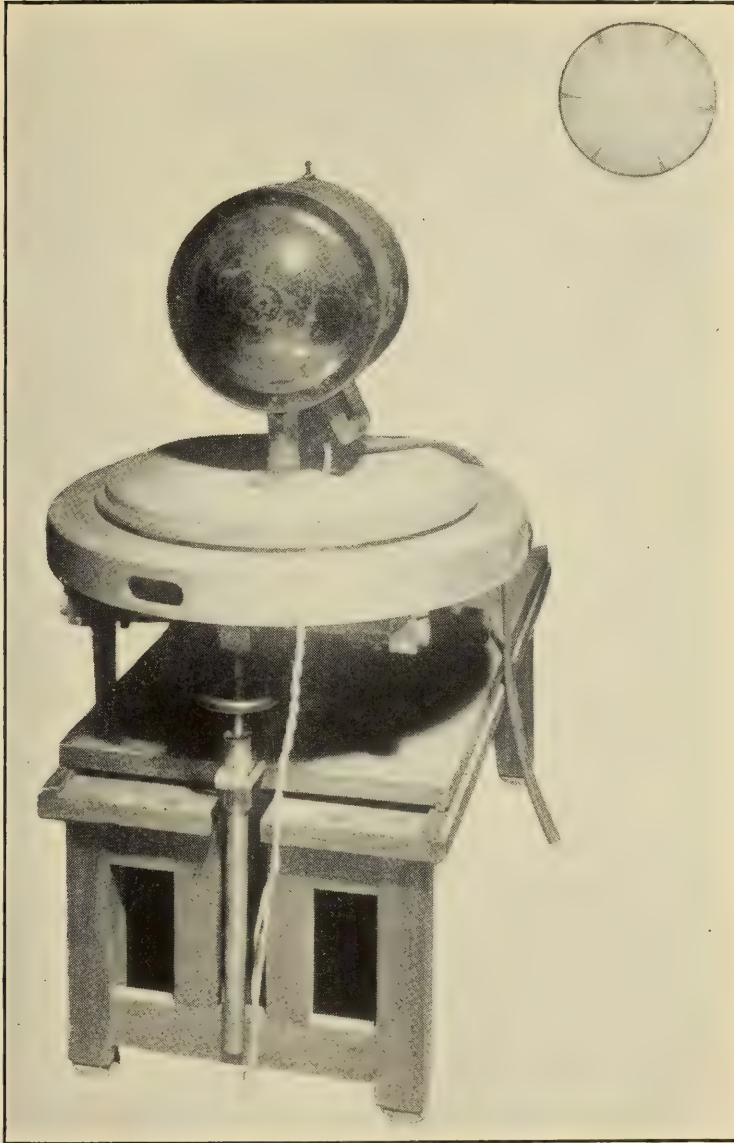


Fig. 2.—Arrangement for photometering a headlight with the integrating hemisphere.
Calibrating lamp left in instrument to show its location.

K	Ratio $\left\{ \begin{array}{l} \text{Reflected light} \\ \text{Direct light} \end{array} \right.$	
	Sphere	Hemisphere
0	0	0
0.1	0.11	0.05
0.2	0.25	0.11
0.3	0.43	0.18
0.4	0.67	0.25
0.5	1.00	0.33
0.6	1.50	0.43
0.7	2.33	0.54
0.8	4.00	0.67
0.9	9.00	0.82
1.0		1.00

TEST EQUIPMENT.

The hemisphere used for this experimental work was part of the 1-meter sphere reported on in connection with the compensating screen described in the 1916 TRANSACTIONS, with such additions as were suggested by the wider field of usefulness of the hemisphere.

SPOT CALIBRATION.

Among the first tests made on the integrating hemisphere was a determination of the effects of light striking different parts at various angles of incidence. For this test a highly concentrated filament lamp was mounted with a condensing lens so as to obtain the maximum concentration of light. This projector was placed on a portable tripod so that the spot of light thrown by it could be moved to any part of the hemisphere, and the direction of incidence could be altered as desired. The lighting equipment was always kept out of the hemisphere, and precautions were taken to eliminate stray light.

Three spot-calibrations were made, first by throwing the light on the hemisphere in a normal direction, second by placing the projector on the axis of the instrument and 1.5 meter from the plane of the opening, and third, by moving the projector so that the beam was kept parallel to the axis. This last condition simulates conditions when photometering a projector placed a long way from the hemisphere. The 1.5 meter position corresponds to the location of a wide angle flood lighter, while the central position is suitable for all distributing units.

The spot of light from the condensing lens was 90 mm. in diameter and at normal incidence covered an arc of 10° on the hemisphere. The reduced photometer readings for various positions of the spot on the hemisphere are given below for the three locations of the light source.

PHOTOMETER READINGS.

Angle on Hemisphere ...	0	10°	20°	30°	40°
Normal	0.330	0.993	1.000	1.004	1.009
1.5 M	0.330	0.993	1.002	1.009	1.016
Parallel	0.330	0.996	1.005	1.012	1.024
Angle on Hemisphere ...	50°	60°	70°	80°	90°
Normal	1.018	1.000	0.996	0.986	0.980
1.5 M	1.026	1.020	1.031	1.015	1.010
Parallel	1.054	1.065	1.076	1.064	1.060

The light at 0° strikes the back of the screen and reaches the window only after reflection from both the screen and hemisphere. The area of the screen is 1.3 per cent. of the hemispherical area. It would be better if this screen were smaller. The present screen is probably best suited for the 2-meter sphere, where the relative area would be only 0.3 per cent. In order to make comparisons easier the photometer readings were reduced so that the normal reading was 1.000 at every angle. These values were plotted, and smooth curves drawn giving results as follows:

COMPARATIVE PHOTOMETER READINGS.

Angle on Hemisphere ...	0	10°	20°	30°	40°
Normal incidence	100.0	100.0	100.0	100.0	100.0
1.5 M position	100.0	100.0	100.0	100.2	100.6
Parallel beam	100.0	100.0	100.2	100.9	102.0
Angle on Hemisphere ...	50°	60°	70°	80°	90°
Normal incidence	100.0	100.0	100.0	100.0	100.0
1.5 M position	101.2	101.9	102.7	103.5	104.4
Parallel beam	103.5	105.5	107.7	110.1	112.7

EFFECT OF PAINT CHARACTERISTICS.

An inspection of the above results shows that a photometric test on a unit 1.5 m. from the opening of the hemisphere would give results about 2 per cent. high; when testing a projector at a long radius the results would be about 4 per cent. high, and in both cases the photometric result would be influenced somewhat by the distribution of light within the hemisphere. This is a new phase of the difficulty overcome by the compensating screen but it is not to be corrected by the screen unless several

different screens are made for the different positions of the test unit. This would not be at all satisfactory because if a screen were constructed to photometer a unit at 1.5 m. from the opening it would not give exact readings on the calibration lamp. The use of the present screen with calculated correction factors for various positions of the test unit has not been seriously considered. These correction factors do not offer a real solution of the difficulty because they cannot take into account the distribution of light from the unit under test.

CORRECTING DEVICE FOR PARALLEL LIGHT.

Practically all projection units give a beam of light that is approximately symmetrical about the axis of the beam. Advantage may be taken of this fact to secure a complete adjustment for any point on the axis of the integrating instrument, and one other point may be given a practically complete adjustment by the same device.

The device adopted consists simply of six wedge-shaped vanes made of black cardboard and arranged in a circle in front of the opening of the hemisphere. The bases of the wedges are 0.5 m. (the radius of the hemisphere) from the photometric axis, and the points are turned in toward a common center. The comparative photometric readings just given show that light coming parallel to the axis gives readings 12.7 per cent. high when it strikes at the edge of the hemisphere. The widths of the bases of the wedges are so proportioned that they interrupt just sufficient light to bring the photometric reading down to 100 at the edge. The widths of the other sections of the wedges are proportioned in like manner to make all points read 100 for equal quantities of light. The calculations for the parallel light correction follow:

Angle on hemisphere	Radius	Circumference	Photometric reading	Reduction	Width of single wedge
0	0	0	100.0	0	0
10°	0.089 m.	0.531 m.	100.0	0	0
20°	0.173	1.092	100.2	0.002	0.4 mm.
30°	0.254	1.595	100.9	0.009	2.4
40°	0.327	2.058	102.0	0.020	6.9
50°	0.389	2.450	103.5	0.034	13.9
60°	0.440	2.770	105.5	0.052	24.0
70°	0.477	3.000	107.7	0.072	36.0
80°	0.500	3.142	110.1	0.092	48.2
90°	0.508	3.193	112.7	0.113	60.1

The action of this set of six wedges will be recognized as being the opposite of the action of the compensating screen. The screen collected light from the relatively least effective sections of the hemisphere and brought all sections up to the effectiveness of the 90° zone. The wedges on the other hand bring all zones down to the effectiveness of the 0° zone where all positions on the axis give equal readings without correction.

CORRECTION FOR 1.5 M. POSITION OF UNIT.

It cannot be assumed that because the constant of the hemisphere has been reduced to equality at the two extreme lamp positions (the maximum available range in the laboratory is about 27 m., which approximates our hypothetical position at infinity) all positions between will be in calibration. The 1.5 m. position requires a reduction of 4.4 per cent. in the light from the 90° zone to the reading window. The amount of light intercepted in the parallel beam is the same for all positions of the set of wedges, but for short test distances the amount of light intercepted falls off rapidly if the wedges are moved away from the hemisphere. The light entering the hemisphere from the 1.5 m. point is in the form of a cone with its base at the rim of the hemisphere and its apex at the light source. The intensity of the light in the outer layer of this cone should be reduced 4.4 per cent.

The problem of placing the wedges for any intermediate position becomes complicated by the fact that the shadow of the wedge is larger than the wedge itself, and the degree of enlargement varies with each position of source and wedge. By trial, it has been found that when the wedges are 20 cm. out from the plane of the opening, the required and actual reduction are as follows:

Angle	Required reduction	Actual reduction
90°	0.042	0.052
80°	0.034	0.040
70°	0.027	0.026
60°	0.019	0.020
50°	0.012	0.013
40°	0.006	0
30°	0.002	0
20°	0	0
10°	0	0
0	0	0

These calculations were carried out with the aid of Fig. 3 and the following formula:

$$DQ = R \sin a \frac{150 - x}{150 + R \cos a} \text{ centimeters} \dots\dots (5)$$

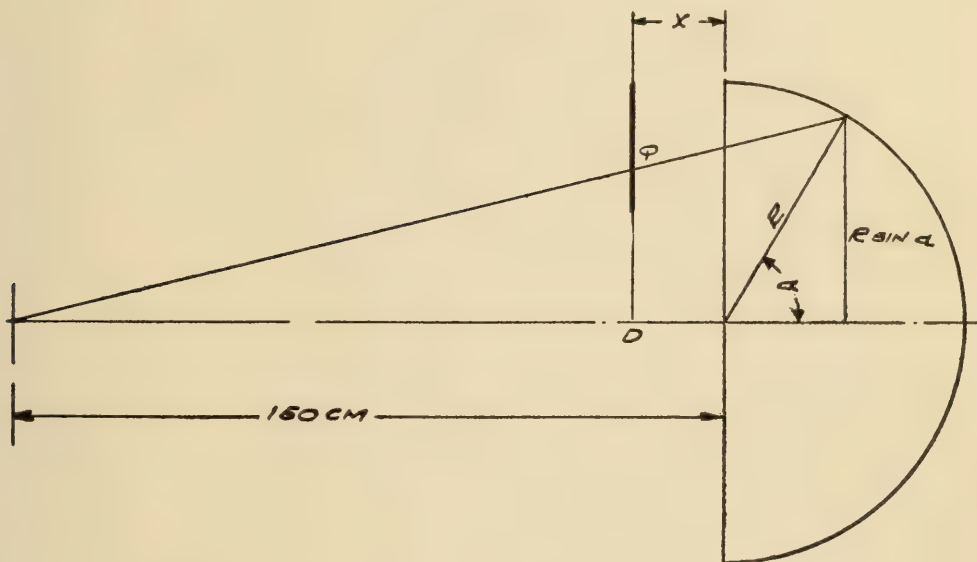


Fig. 3.

The width, W_0 , of the wedges at radius DQ was obtained from plotted values of radii and wedge width. The width of the shadow is

$$W = W_0 \frac{150 + R \cos a}{150 - x} \text{ centimeters} \dots\dots\dots (6)$$

and the reduction r , of the photometer reading due to the shadow of width W in the illuminated zone a is

$$r = \frac{W}{2\pi R \sin a} \text{ numeric} \dots\dots\dots (7)$$

The tabulated values of the reductions show a fair agreement with the required reduction, and it will probably be found that the instrument equipped with these wedges is nearly independent of the distance to the projector or the distribution of the light from the latter. This finished the design work on the hemisphere as used for photometering projectors and probably brings the inherent accuracy of the instrument well within the bound of good photometric practice.

2-METER HEMISPHERE.

Plans have been made for equipping a 2-meter hemisphere with a compensating screen and wedges, and in addition have an iris shutter arranged in front of the instrument so that any angular opening may be obtained. The 1-meter hemisphere is not large enough to give accurate angular dimensions at distances necessary for some of the wide angle flood lighting units. To test a 10° floodlighting unit for total flux it would have to be placed within 5.72 m. of the photometer. This is too close for the best results, but by using the 2-meter hemisphere a working radius of 11.44 m. will be available and relatively accurate work can be done on flux determinations.

LOCATION OF DISTRIBUTING UNIT AND ITS EFFECT.

The contemplated use of the hemisphere as an integrator for distributing units involves placing the comparison lamp and test units with their axes and light centers in the plane of the opening. This places the unit half within the hemisphere and as a result there occurs a rather novel and interesting phenomena. It will be demonstrated shortly that the average illumination within the hemisphere may be either increased or decreased, depending upon the size, shape and reflecting properties of the unit. A test unit, or other object, placed within a sphere invariably decreases the brightness, often to a very serious extent. The change in brightness in the hemisphere will rarely exceed 5 per cent., either plus or minus, and will more ordinarily be only 1 or 2 per cent.

Each symmetrical unit was tested for both absorption and radiation and then rotated through 180° and tested again. The average values were used. Unsymmetrical units were tested in four positions 90° apart. The average of the 0° and 180° readings were checked against the 90° and 270° readings. It is necessary in practice to photometer every unit in two positions 180° apart whether it is supposed to be symmetrical or not. Very few units were found to have even approximately the same light flux in the two opposite hemispheres.

NON CENTRAL POSITION OF LIGHT SOURCE.

In test work it is often necessary to have two light sources in

the instrument at once, and only one can be in the center. In the test work described later the test unit was placed about midway between the center and top and the standard midway between the center and bottom of the hemisphere. These positions were determined upon after a test had shown that the photometer readings were independent of the position of a bare lamp to within 25 cm. of the edge. From the center to 20 cm. ($= 0.4 R$) the photometer read 100. At 25 cm. it read 100.7. The units were placed at the edge of the working range so as to use the smallest size screen between them.

IDEAL CASE ASSUMED.

In developing the theory of the 'foreign body' in the hemisphere the convention of assuming an ideal case has been adhered to. Other approximations have been made as the occasion requires, and the entire mathematical investigation is on an equal footing with the theory of the 'foreign body' in a complete sphere.

ABSORPTION OF LIGHT BY TEST UNIT.

To determine the absorption of light by the test unit let us consider an ideal case, where the hemisphere is evenly illuminated by some source and the foreign body has the simplest possible form and most easily investigated position. In Fig. 4 a spherical body of radius r is shown located in the generating center of a hemisphere of radius R . Assume for the time being that the body is a perfect absorber. The opening of the hemisphere is always masked with suitable black screens to absorb all light passing out through the plane of the opening and also to exclude light from outside sources. Viewed from any point in the zone AKD, the foreign body will appear as a black disk against a black background; the body will therefore have absolutely no direct effect upon the brightness of points within this zone.

From the point C, the body appears as a half disk concealing an area of radius $BA = 2r$ on the opposite hemisphere wall. The size of the concealed area is

$$A = \frac{1}{2}\pi (2r)^2 = 2\pi r^2 \text{ sq. cm.} \dots \dots \dots (8)$$

As the point of observation moves from C to D the concealed area decreases until it reaches zero at the latter position.

Let R be the radius of the hemisphere, in centimeters.
 Let r be the radius of the foreign body in centimeters.
 Let B_0 be the initial brightness of the hemisphere in lamberts and
 Let a be the plane angle measured from the axis OK .

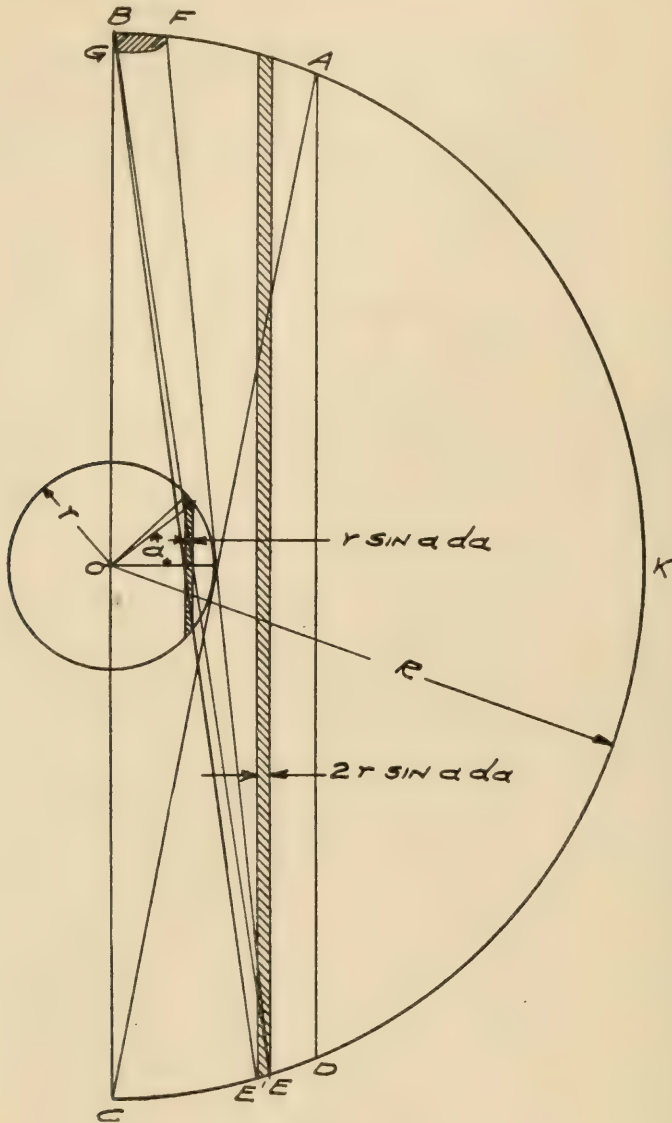


Fig. 4.

From any point, E , Fig. 4 the foreign body conceals an area

$$\begin{aligned}
 BFG &= 8 \int_0^a r^2 \sin^2 a \, da \text{ sq. cm.} \\
 &= 4 r^2 a - 2 r^2 \sin 2a \text{ sq. cm.} \dots \dots \dots (9)
 \end{aligned}$$

The plane in which angle a , Fig. 4, is measured is at right angles to the plane of the paper.

The illumination of the zone EE' on the hemisphere is then, on the first reflection of light

$$\begin{aligned} E &= B_0 \frac{\text{Area of hemisphere} - \text{concealed area BFG}}{\text{Area of sphere}} \text{ phots} \\ &= B_0 \frac{2\pi R^2 - 4r^2 a + 2r^2 \sin 2a}{4\pi R^2} \text{ phots} \\ &= \frac{1}{2} B_0 \left(1 - \frac{2r^2 a}{\pi R^2} + \frac{r^2 \sin 2a}{\pi R^2} \right) \text{ phots} \dots\dots\dots (10) \end{aligned}$$

The area of the zone EE' is

$$\begin{aligned} dA &= 2\pi R (2r \sin a \, da) \text{ sq. cm.} \\ &= 4\pi R r \sin a \, da \text{ sq. cm.} \dots\dots\dots (11) \end{aligned}$$

if we consider it to be cylindrical instead of spherical.

The flux falling upon zone EE' is then

$$dF = E \, dA \text{ lumens} \dots\dots\dots (12)$$

and by integrating between the limits $a = 0$ and $a = \frac{\pi}{2}$ we may determine the quantity of light reflected on the first reflection into the zone CD that is effected by the presence of the foreign body.

$$\begin{aligned} F &= \int_0^{\frac{\pi}{2}} E \, dA = B_0 \left(2\pi R r \int_0^{\frac{\pi}{2}} \sin a \, da - \frac{4r^3}{R} \int_0^{\frac{\pi}{2}} a \sin a \, da + \right. \\ &\quad \left. \frac{2r^3}{R} \int_0^{\frac{\pi}{2}} \sin a \sin 2a \, da \right) = B_0 \left[-2\pi R r \cos a - \frac{4r^3}{R} (\sin a - a \cos a) \right. \\ &\quad \left. + \frac{2r^3}{R} \left(\frac{\sin a}{2} - \frac{\sin 3a}{6} \right) \right]_0^{\frac{\pi}{2}} = B_0 \left(2\pi R r - \frac{4r^3}{R} + \frac{4r^3}{3R} \right) = B_0 \left(2\pi R r - \right. \\ &\quad \left. \frac{8r^3}{3R} \right) \text{ lumens.} \dots\dots\dots (13) \end{aligned}$$

The zone AKD has an area

$$A' = 2\pi R (R - 2r) \text{ sq. cm.} \dots\dots\dots (14)$$

and it receives on the first reflection an illumination

$$E' = \frac{1}{2} B_0 \text{ phots} \dots\dots\dots (15)$$

from the entire hemisphere. The lumens on this zone are

$$\begin{aligned} F' &= E' A' \\ &= B_0 (\pi R^2 - 2\pi Rr) \text{ lumens} \dots (16) \end{aligned}$$

The total light received by the entire hemisphere on the first reflection is then

$$F_0 = F + F' = B_0 \left(2\pi Rr - \frac{8r^3}{3R} + \pi R^2 - 2\pi Rr \right) \quad (17)$$

$$= B_0 \left(\pi R^2 - \frac{8r^3}{3R} \right) \text{ lumens} \dots \dots \dots (18)$$

A hemisphere of brightness B_0 reflects

$$F = 2\pi R^2 B_0 \text{ lumens} \dots \dots \dots (19)$$

of which just one-half is again incident upon the walls, or

$$F = \pi R^2 B_0 \text{ lumens} \dots \dots \dots (20)$$

This is the same as the first part of the right-hand member of equation (17) and the quantity

$$F' = \frac{8r^3}{3R} B_0 \text{ lumens} \dots \dots \dots (21)$$

from the same equation represents the light lost on the foreign body that would otherwise be incident upon the hemisphere. This is the loss on the first reflection only. The total loss will be determined later.

It should be noted that from Fig. 4 we can arrive at the conclusion that the hemisphere will be more accurate for a given unit than will a corresponding sphere. The distribution of light from the test unit and working standard will be different, and the initial distribution of wall brightness will be different for the two sources. We may assume that the further reflection of light in the integrator will be independent of the first distribution of brightness on the sphere or hemisphere walls. Thus it is only the first reflection that will give rise to a different degree of absorption by the test unit of the light from the two sources. In the sphere the test unit interferes with the first reflection from every point, while in the hemisphere it has absolutely no effect on the free reflection from the greater part of the instrument, and it is only in the zone around the edge, COB Fig. 4 that interference takes place to the extent that occurs in all parts of the sphere.

is shown located in the center of the plane of the opening of a hemisphere of radius R . Any point P on the body receives light reflected from the hemisphere, or as much of it as is visible from the point P . A portion, K'' , of the light received is reflected by pure diffusion, part returning to the hemisphere and part escaping through the opening. The proportion in each case is determined by the solid angle included by the section of the hemisphere visible from the point P . The boundaries of the visible section of hemisphere are formed by a plane tangent to the foreign body at P and a conical surface radiating from P and meeting the edge of the hemisphere. The determination and handling of this curved surface involves difficulties whose solution is entirely beyond the purpose of this investigation. The work is greatly simplified if in place of the curved surface we take a plane PD parallel to the plane of the opening as one of the boundaries of the visible luminous area. The use of this plane can be partly justified by the fact that there is a point P' symmetrically placed outside of the plane of the opening that is effected in an opposite manner by the assumption of a parallel bounding plane $P'D'$. It should also be noted that about the poles Q and Q' and around the equator BF of the reflecting body this method yields exact results.

The brightness of the hemisphere being B_0 lamberts, the illumination of the element P is

$$E = B_0 \frac{2\pi [1 + \sin(\frac{\pi}{2} - a)]}{4\pi} = B_0 \frac{1 + \cos a}{2} \text{ phots.} \dots (22)$$

There is a circular zone of points similarly placed and the area of this zone (see the figure) is

$$dA = 2\pi r^2 \sin a \, da \text{ sq. cm.} \dots \dots \dots (23)$$

The quantity of light falling upon the zone is numerically equal to the illumination times the area, or

$$dF = \pi r^2 B_0 (1 + \cos a) \sin a \, da \text{ lumens} \dots \dots (24)$$

The proportion of this light that strikes the hemisphere after reflection is proportional to the solid angle subtended by the visible hemisphere, and after multiplying by the coefficient of reflection, K'' of the foreign body, we get for the total returned light

$$\begin{aligned}
 F &= K'' \pi r^2 B_0 \int_0^\pi \frac{(1 + \cos a)^2}{2} \sin a \, da \\
 &= \frac{1}{2} \pi r^2 K'' B_0 \left(\int_0^\pi \sin a \, da + 2 \int_0^\pi \sin a \cos a \, da + \int_0^\pi \sin a \cos^2 a \, da \right) \\
 &= \frac{1}{2} \pi r^2 K'' B_0 \left(-\cos a + \sin^2 a - \frac{1}{3} \cos^3 a \right)_0^\pi \\
 &= \frac{4}{3} \pi r^2 K'' B_0 \text{ lumens} \dots \dots \dots (25)
 \end{aligned}$$

This expression for the amount of light reflected back into the hemisphere by a diffusing sphere of radius r is fairly exact only for a value of r that is very small in comparison with R , the radius of the hemisphere. The error is not large for moderate values of r , say three-tenths of the radius of the hemisphere, which is about the maximum size of unit that will be tested in this integrator.

The effect of this reflected light in connection with the obstruction of light by the spherical unit will be investigated after an expression has been found for the light reflected into the hemisphere by a spherical mirror. This spherical mirror is supposed to typify lighting units that have a high degree of specular reflection on the surfaces illuminated by reflected light.

REFLECTION BY SPECULAR SURFACE.

In Fig. 6 a spherical mirror of radius r is shown located at the center of a hemisphere of radius R . An observer at the point I sees the point C on the perimeter of the hemisphere reflected in the mirror at a point E , 45° from the OI axis. The point of reflection E is always 45° regardless of the relative values of r and R . The image of the hemisphere covers an arc EGE' on the mirror and the apparent plane area of this image viewed from the point I is

$$A_1 = \pi (r \sin 45^\circ)^2 = \frac{1}{2} \pi r^2 \text{ sq. cm.} \dots \dots \dots (26)$$

The brightness of the hemisphere being B_0 and the coefficient of reflection of the mirror being K''' , the illumination, by light from the mirror at the point I , is

$$E = \frac{A_1 B_0 K'''}{\pi (IE)^2} \text{ phots} \dots \dots \dots (27)$$

and if the radius of the mirror is small as compared with the radius of the hemisphere

$$\begin{aligned} E_1 &= \frac{A_1 B_0 K'''}{\pi R^2} \text{ phots} \\ &= \frac{r^2 B_0 K'''}{2 R^2} \text{ phots} \dots\dots\dots (28) \end{aligned}$$

that is, one-half of the projected area of the mirror is active in reflecting light to the point I.

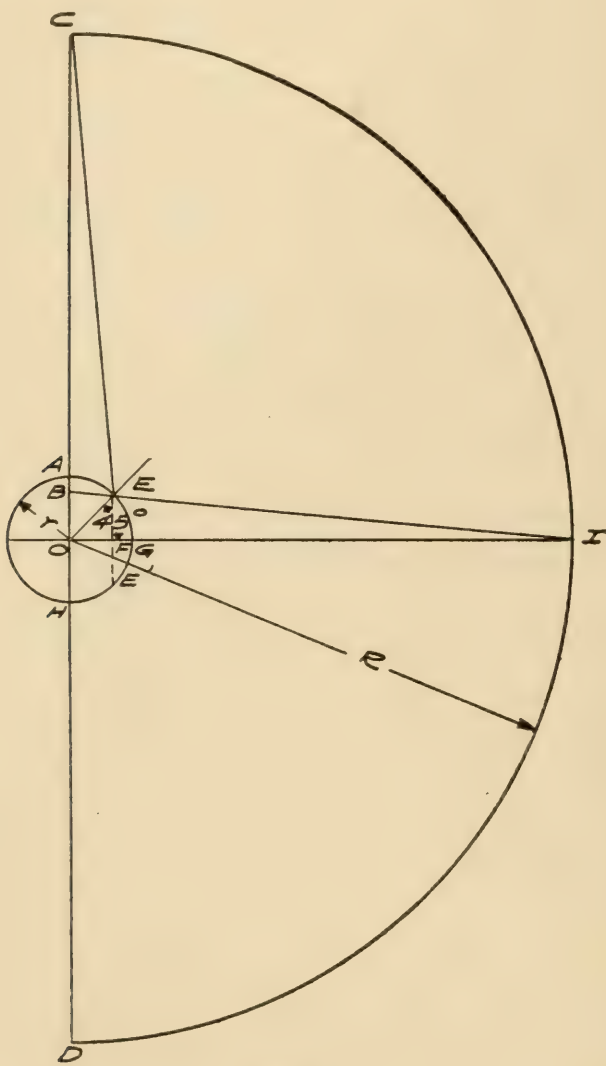


Fig. 6.

It may be seen by inspection that, viewed from any point on the rim of the hemisphere, all visible points on the arc AEE'H will

reflect light from the hemisphere walls, and no light will be reflected from the area of the mirror lying outside of the meridian $H O A$. Here again half the mirror is luminous, and the illumination by mirror at the point D is

$$E_2 = \frac{r^2 B_0 K'''}{2 R^2} \text{ photos} \dots \dots \dots (29)$$

It should be observed that equation (29) is exact for all values of r , while equation (28) is derived by making the assumption that $IE = R$, and hence is an approximation that gives values lower than the true illumination. More importance should be attached to the calculated value at D , because more area is represented by the zone around the rim of the hemisphere and although the illumination at D is less than at any other section, the last equation may be used to represent the entire area. The flux returned to the integrator is then

$$\begin{aligned} F &= 2\pi R^2 E_2 \\ &= \pi r^2 B_0 K''' \text{ lumens} \dots \dots \dots (30) \end{aligned}$$

With the aid of equations (21) and (25) it is possible to calculate the effect of a diffusing unit on the photometric reading, or using (21) and (30) the effect of a spherical mirror may be calculated. A comparison of the last equation and the corresponding equation (25) for a diffusing unit shows that the latter returns one-third more light to the hemisphere.

SYMBOLS USED FOR HEMISPHERE.

Let F_0 be the total flux entering the integrator.

Let F' be the light obstructed by the test unit.

Let F'' be the light reflected by pure diffusion.

Let F''' be the light reflected by specular reflection.

Let A be the area of the test unit.

Let K be the coefficient of reflection of the hemispherical surface.

Let K'' be the coefficient of reflection of the diffusing unit.

Let K''' be the coefficient of reflection of the specular unit.

Let B_0 be the initial brightness of the hemisphere.

EQUATION FOR DIFFUSING UNIT.

Solving first for the effect of the diffusing unit, we have

$$B_0 = \frac{F_0 K}{2\pi R^2} \text{ lamberts} \dots \dots \dots (31)$$

for the brightness due to direct light only. Of the total incident flux F_0 the part KF_0 will be reflected, and half of this will, in the absence of a test unit, escape from the instrument. Including the obstruction and reflection by the unit, we have available for the first illumination by reflected light

$$F_1 = \frac{1}{2} KF_0 - F' + F'' \text{ lumens} \dots \dots \dots (32)$$

From equation (31) and (21) we have for the obstructed light

$$F' = \frac{8}{3} \frac{r^3}{R} B_0 = \frac{4}{3\pi} \frac{F_0 K r^3}{R^3} \text{ lumens} \dots \dots \dots (33)$$

and the reflected light is from equations (25) and (31)

$$F'' = \frac{4}{3} \pi r^2 K'' B_0 = \frac{2}{3} \frac{r^2 K'' F_0 K}{R^2} = \frac{2K K'' F_0 r^2}{3R^2} \text{ lumens} \dots (34)$$

substituting (33) and (34) in (32) the net light available for the first illumination of the hemisphere by reflection is

$$F_1 = \frac{1}{2} KF_0 - \frac{4K F_0 r^3}{3\pi R^3} + \frac{2K K'' F_0 r^2}{3R^2} \dots \dots \dots (35)$$

$$= \frac{1}{2} KF_0 \left(1 - \frac{8}{3\pi} \left(\frac{r}{R} \right)^3 + \frac{4K''}{3} \left(\frac{r}{R} \right)^2 \right) \text{ lumens} \dots (36)$$

The brightness due to reflected light alone is

$$B_1 = \frac{F_1 K}{2\pi R^2} = \frac{F_0 K^2}{4\pi R^2} \left[1 - \frac{8}{3\pi} \left(\frac{r}{R} \right)^3 + \frac{4K''}{3} \left(\frac{r}{R} \right)^2 \right] \quad (37)$$

Similarly

$$\begin{aligned} F_2 &= \frac{1}{2} KF_1 - F'_1 + F''_1 = \frac{1}{2} KF_1 - \frac{4KF_1 r^3}{3\pi R^3} + \frac{2K K'' F_1 r^2}{3R^2} \\ &= \frac{1}{2} KF_1 \left(1 - \frac{8}{3\pi} \left(\frac{r}{R} \right)^3 + \frac{4K''}{3} \left(\frac{r}{R} \right)^2 \right) \\ &= \frac{1}{4} K^2 F_0 \left(1 - \frac{8}{3\pi} \left(\frac{r}{R} \right)^3 + \frac{4K''}{3} \left(\frac{r}{R} \right)^2 \right)^2 \text{ lumens} \dots (38) \end{aligned}$$

and the brightness due to the second reflection is

$$B_2 = \frac{F_2 K}{2\pi R^2} = \frac{K^3 F_0}{8\pi R^2} \left(1 - \frac{8}{3\pi} \left(\frac{r}{R} \right)^3 + \frac{4K''}{3} \left(\frac{r}{R} \right)^2 \right)^2 \text{ lamberts} (39)$$

For the total brightness due to the addition of an infinite series of reflections we have

$$\begin{aligned}
 B &= B_0 + B_1 + B_2 + \dots \\
 &= \frac{F_0 K}{2\pi R^2} + \frac{F_0 K^2}{4\pi R^2} \left(1 - \frac{8}{3\pi} \left(\frac{r}{R} \right)^3 + \frac{4K''}{3} \left(\frac{r}{R} \right)^3 \right) \\
 &+ \frac{F_0 K^3}{8\pi R^2} \left(1 - \frac{8}{3\pi} \left(\frac{r}{R} \right)^3 + \frac{4K''}{3} \left(\frac{r}{R} \right)^2 \right)^2 + \dots \\
 &= \frac{F_0 K}{2\pi R^2 \left(1 - \frac{K}{2} \left[1 - \frac{8}{3\pi} \left(\frac{r}{R} \right)^3 + \frac{4K''}{3} \left(\frac{r}{R} \right)^2 \right] \right)} \text{ lamberts (40)}
 \end{aligned}$$

and this is the characteristic equation of hemisphere with a spherical diffusing unit at its center.

EQUATION FOR SPECULAR UNIT.

It was pointed out at the conclusion of the derivation of the quantity of light reflected by a specular sphere that it returned three-fourths as much as an equal diffusing sphere. We may write directly from (40)

$$B = \frac{F_0 K}{2\pi R^2 \left(1 - \frac{K}{2} \left[1 - \frac{8}{3\pi} \left(\frac{r}{R} \right)^3 + K''' \left(\frac{r}{R} \right)^2 \right] \right)} \text{ lamberts (41)}$$

for a specular unit, when K''' is its coefficient of reflection.

APPROXIMATION FOR MIXED SPECULAR AND DIFFUSE REFLECTION.

Many, if not all, lighting units reflect light by a process intermediate between pure diffusion and specular reflection. As a working compromise a mean between K'' and K''' may be used with a coefficient of 1.2. Also in place of $\frac{8}{3\pi}$ we may use 0.8, giving

$$B = \frac{F_0 K}{2\pi R^2 \left(1 - \frac{K}{2} \left[1 - 0.8 \left(\frac{r}{R} \right)^3 + 1.2K' \left(\frac{r}{R} \right)^2 \right] \right)} \text{ lamberts (42)}$$

Where K' is the average coefficient of reflection.

The expression for the brightness of an empty hemisphere is

$$B_0 = \frac{F_0 K}{2\pi R^2 \left(1 - \frac{K}{2} \right)} \dots \dots \dots (43)$$

and the ratio of the brightness with and without the foreign body is given by equation (44) at the top of Fig. 7.

In Fig. 7 values of R_h are plotted for various values of $\frac{r}{R}$ and K' . In practice there is seldom occasion to photometer a unit corresponding to the units assumed for the above investigation.

$$R_h = \frac{1 - \frac{\kappa}{2}}{1 - \frac{\kappa}{2} \left[1 - 0.8 \left(\frac{r}{R} \right)^3 + 1.2 K' \left(\frac{r}{R} \right)^2 \right]} \quad (44)$$

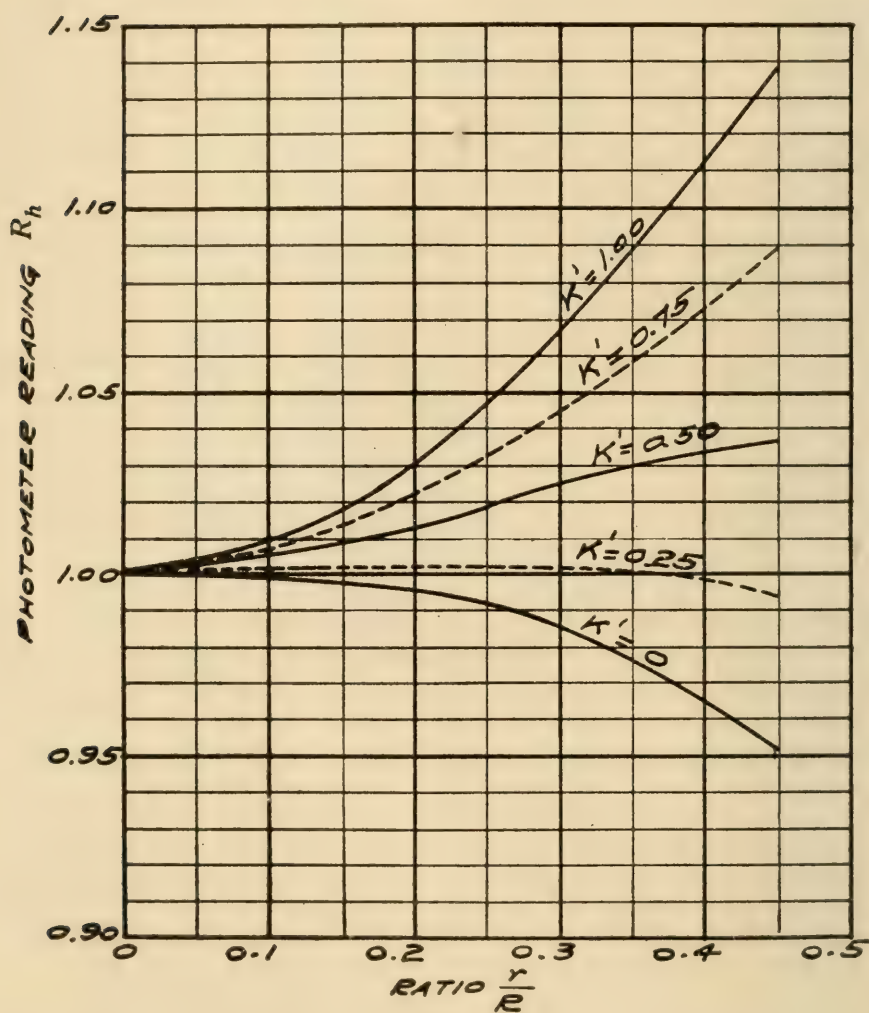


Fig. 7.

The reasons for supposing that this integrator possesses points of superiority over the complete sphere are directly based on the above mathematics, and it was originally intended to follow it through with a series of tests with spheres of different sizes and

degrees of diffuse or specular reflection. Unfortunately this has been impossible to do, but a series of tests was carried out in parallel with the regular laboratory work on the distribution and spherical photometers. The results of all work completed to date are given below.

An average figure for the total coefficient of reflection of the ordinary metal reflector is about 0.20, both the inner and outer surfaces being included. The outer surface of a green or blue reflector has a coefficient of from 0.10 to 0.15 and the inner surface may reflect 0.70 but due to the light being trapped the net reflection is reduced to 0.50. The average will in this case, be about 0.20 on account of the greater area presented by the outside surface, which includes the holder or canopy. Such a unit will have practically no effect upon the brightness of the hemisphere, as will be seen by an inspection of the curve for $K' = 0.25$ in Fig. 7. The same unit in the sphere will have a very marked effect; the calculated curve is given in Fig. 1. The probable accuracy of the results is not represented by these two curves, but the accuracy is closely related to the amount of absorption and there is thus reason to expect the improvement noted later in the discussion of the test data.

TEST DATA.

Several tests have been made on projection units. None of these tests have been complete enough to furnish a means for a just opinion; the data may be described as encouraging but not conclusive.

A number of distributing units have been tested in the 2-meter sphere, the 1-meter sphere, the 1-meter hemisphere and the incandescent distribution photometer. In the latter instrument the number of planes in which readings were taken varied with the character of the test unit and in some of the more unsymmetrical reflectors as many as eight complete vertical planes were investigated. It is assumed that the distribution photometer is most nearly correct and the apparent errors are calculated on this basis. This is not necessarily correct, but the agreement between the four instruments lends some weight to this view. The units were selected for variety and particular care was taken to include

as many as possible of the units that experience has shown to be difficult to photometer in the sphere.

PER CENT. INCREASE (+) OR DECREASE (—) IN PHOTOMETER READING.

Reflector		$\frac{r}{R}$		
Material	Outside color		1 m Sphere	Hemisphere
Glass	White	0.15	— 4.2	+1.1
Glass	White	0.20	— 5.7	+3.6
Glass	Clear	0.15	— 7.6	+0.7
Metal	Green	0.12	— 8.0	+0.5
Metal	Green	0.12	— 9.4	+0.3
Glass	Clear	0.24	— 9.8	+3.7
Glass	Clear	0.28	—15.1	+3.2
Metal	Green	0.18	—17.7	+1.0
Metal	Green	0.19	—17.7	+0.3
Metal	White	0.25	—17.7	+5.0
Metal	Green	0.20	—19.2	+1.9
Metal	Green	0.20	—22.1	+0.5
Metal	Green	0.19	—23.4	+0.2
Glass	White	0.32	—26.0	+0.3
Metal	Green	0.24	—26.4	+0.9
Metal	Green	0.26	—26.7	+2.2
Metal	Green	0.23	—27.9	—0.7
Metal	Green	0.26	—28.8	+1.5
Metal	Green	0.26	—30.0	+0.5
Metal	Green	0.30	—33.5	—1.0
Metal	Green	0.31	—36.5	—0.2
Metal	Green	0.32	—40.2	—1.1
Metal	Green	0.31	—44.6	—3.5

The ratio $\frac{r}{R}$ is derived from a mean of the diameter and height of the reflector. The absorption is greatly affected by the shape of the reflector as well as the active reflecting surface. No close relationship between the absorption in the two instruments can be found in the above tabulation. This is due in part to the sphere treating diffuse and specular reflection alike, while the hemisphere distinguished between the two. The absorption values are in good agreement with the curves of Fig. 7, and with several exceptions fall within the predicted region between the curves $K' = 0$ and $K = 0.75$ in Fig. 7.

There are thirty-nine completed tests on the accuracy of the three integrators. In the following table the results are grouped without regard to size or character of unit. It should be men-

tioned in fairness to the 2-meter sphere that the tests on this instrument were with exceptionally difficult units. One was a glass bowl 13 inches in diameter by 14 inches deep with brass suspending chains. Another unit was slightly smaller but lined with colored silk. This silk gave a bad color balance in all instruments, but the color was slightly deeper in the spheres due to the greater amount of light filtered after reflection.

Instrument	No. of tests	Average error Per cent.
1-meter sphere	16	2.90
2-meter sphere	4	1.75
1-meter hemisphere	19	0.78

This group of tests includes several on side lighting units, refractors and the two units mentioned above, but only in isolated instances did it include the units tested for absorption.

ABSTRACT—RECENT DEVELOPMENTS IN
INCANDESCENT LIGHTING.*

BY GEORGE H. STICKNEY.

The intent of the presentation is to cover developments in incandescent lighting which have occurred since the I. E. S.-U. of P. Lecture Course of 1916. Shortage of materials, machinery and labor, coupled with greatly increased demands for lamp output, have restricted developments to some extent. Especially constructed lamps which depart in any particular from standard types are costly and retard production and should therefore be avoided by purchasers wherever possible. In spite of this the lamp manufacturers have experimented with new types of lamps which have appeared promising in order that progress in incandescent lighting may continue. The result of this policy has been the development of floodlighting, blue bulb, stereopticon and moving picture lamps.

The economical production of effective illumination even with so simple a medium as the incandescent lamp, requires skill and good engineering which include always the selection of proper lamps for the service, equipment as with reflectors and the location of the units as to height, spacing, etc. It was on this account that the lamp manufacturers have provided special illuminating engineering departments which have been influential in advancing the practice of good lighting.

In spite of the economic superiority which has resulted in the rapid substitution of Mazda for carbon and Gem lamps, there has recently been a slight increase in the demand for carbon lamps. Manufacturing equipment is not provided for increasing the output of carbon lamps. This demand is due presumably to their use in emergency construction work in which proper lighting has not been planned. While there is some small necessary demand for carbon lamps, yet in most cases Mazda lamps, particularly of the larger sizes, can be used successfully and to better advantage. Not only does the Mazda lamp offer a very considerable current economy, but when installations are properly designed the in-

* A paper presented before the Chicago Section of the Illuminating Engineering Society, Chicago, Illinois, October 18, 1917.

stallation and maintenance costs are generally less than with carbon lamps.

In the past factory lighting has tended to lag behind some other classes such as commercial lighting. A few large and progressive manufacturers have formed the exception to the general rule. On this account our manufacturing processes have suffered from costs which have been too high and production and quality which have been too low; accidents have been too frequent. The recent industrial expansion has brought about a new condition. The extensive operation of night shifts under artificial light has directed attention to lighting effectiveness and the need for increasing output has led manufacturers to avail themselves of the advantage of good industrial lighting much more generally than in the past. Prominent in this new development has been the more general use of the larger sizes of Mazda C lamps. This has brought a need for diffusing the light from its more concentrated filament. It has been found that bowl frosted Mazda C lamps are successful even where exposed to smoke, dust and oil, though as in all lighting systems, a regular cleaning system promotes economy. A device applicable where a high degree of diffusion is desired is that of a metal reflecting cap fitting snugly about the lower half of the lamp bulb and reflecting the light which falls upon it to a large reflector above the lamp for redistribution. Either a frosted Mazda C lamp with dome type reflector or the reflecting cap with large diameter upper reflector may be used with distinct advantage in most industrial work.

ABSTRACT—THE LIGHTING ART; ITS PRACTICE AND
POSSIBILITIES IN INTERIORS.*

BY M. LUCKIESH.

Variety of direction, intensity, distribution and careful choice of the color quality of light are important considerations in proper illumination of interiors. To "paint" with light as with pigments is an art which has unlimited possibilities and practical applications. Psychiological and physiological aspects are important factors.

To secure variety in lighting and to avoid unsightly outlets and wiring it is necessary to provide several baseboard outlets in each room. The decoration, including the hard-wood finishings, wall covering, door and window mouldings, etc., are matters of vital import in preparing lighting specifications—co-operation between the architect and the lighting specialist is extremely desirable. A correct concept of the finished appearance of the interior must be had by both.

The householder should not be too desirous of curtailing on lighting fixtures and wiring, when the effectiveness of his home depends so much upon proper illumination—and the cost as compared to the total is so negligible. A fixture should first be designed to give intensity, and direction to the light—the outline and finish of the fixture are of secondary importance but should fit in with the decorative scheme of furnishings. Tinted lamps are being developed to obtain pleasing "atmospheres" of color. The illumination must bring out the decorations of the room, must produce high lights and shadows, emphasize color qualities, and represent the individuality of the occupants in so far as good taste is not transgressed.

Scientific research and development and the cordial co-operation of the architect, home builder, lighting specialist and distributors will do much to attain the ideal.

* A paper presented before the Chicago Section of the Illuminating Engineering Society, Chicago, Illinois, February 21, 1918.

ABSTRACT—THE AESTHETICS OF STREET LIGHTING.*

BY M. LUCKIESH.

There is an important middle ground between that occupied exclusively by architects and that occupied by engineers in which there is a large opportunity for illuminating engineers to perform a service. In street lighting this opportunity lies largely in the improvement of existing conditions. This phase of the subject might well be included under a caption "Cleaning up the Front Yards of the City." To a considerable extent the city planning movement neglects the streets. Curbs are lined with all sorts of obstructions, such as mail boxes, trolley poles, telegraph poles, etc. The remedy for this lies in the further development of American taste. The architect is leading in this direction.

Improved appearance of the streets develops patriotism and civic pride, and helps business. To improve the appearance of the streets it seems to me to be necessary principally to harmonize details. Ours is a new country. We have just passed through the stage of impetuous development. Things have had to be done quickly, and sometimes cheaply. We are now getting to the point, or at least may hope to arrive there after the war, when we can consider to a greater extent the development of beauty in our construction work.

(Numerous illustrations, most of which were prepared by Mr. S. E. Doane, were presented to show good and bad practice in regard to construction in the streets for lighting.)

In discussion Mr. W. J. Serrill endorsed the speaker's emphasis of the importance of good daylight appearance of lighting construction. Pleasing lamp posts ornament a street. Concrete posts are particularly useful in this connection. Pleasing street lighting systems beautify a street at night. White way equipment, sign lighting, etc., ought to be artistic by daylight as well as by night.

Mr. E. K. Price, of the Philadelphia Park Commission, described improved street appearance in parts of Philadelphia as

* A paper presented before the Philadelphia Section of the Illuminating Engineering Society, Philadelphia, Pa., March 15, 1918.

a result of mounting trolley wires from building fronts instead of from poles. Artistic poles elsewhere are employed with good effect. Flood lighting of handsome buildings likewise is favored. Electric sign fixtures are often eye-sores in the daytime.

Mr. Thomas Sproule emphasized the handicap of limited funds which prevented artistic treatment of lighting construction. Wherever practicable, poles and circuits are run in the rear of houses instead of on the streets. Where the cost can be defrayed, the wires are run underground.

Mr. Stecher emphasized the practical difficulties in the way of following installation practice which results in the best appearance of the street.

Mr. Luckiesh in closing the discussion stated that the architecture of city streets is in advance of the illuminating engineering. He urged improved street lighting, uniformly installed, which would reveal the buildings. To be satisfactory aesthetically, the illumination must be free from glare.

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ILLUMINATING ENGINEERING AS A COMMERCIAL FORCE.*

SOME EVIDENCE OF ITS IMPORTANCE AND UTILITY
IN THE CENTRAL STATION FIELD.

BY O. R. HOGUE, C. L. LAW AND E. E. WHITEHORNE.

Synopsis: General inattention to the actual purpose of illuminating engineering is causing much of the apathy toward the development of better lighting among utilities. These practical objectives are—1. To develop new lighting business from new customers. 2. To improve the lighting of present users, raise the standard of illumination and the resulting revenue. 3. To promote good service and satisfaction among customers and the company's property and good repute. The organization needed for such work is illustrated in the case of utilities in cities of varying size; with detailed description of the Bureau of Illuminating Engineering of the New York Edison Company. The definite results which are obtained from this commercial practice of illuminating engineering are cited from the experience of the Commonwealth Edison Company, Chicago, Ill., the Central Hudson Gas & Electric Company, Poughkeepsie, N. Y., and the Rochester Railway & Electric Company, Rochester, N. Y.; also other evidences of achievement in incidents reported from other cities with some further comment on the indirect influences of such illuminating engineering work for increasing industrial output, improving conditions in the workman's home and the development of the science itself.

There is a great deal of unfortunate misunderstanding as to the commercial purpose and practical value of the science of illuminating engineering to the lighting industries. Its laws and principles have been discussed and analyzed through years of evolution, its practices have been defined, its ever growing wealth of experience has been related and passed on for wider use, but

*A paper prepared under the auspices of the Lighting Sales Bureau of the National Electric Light Association for the 1916-17 Correspondence Convention of the Illuminating Engineering Society.

men have kept on thinking of it largely as a scientific propaganda. The most important fact remains that this same science of illuminating engineering has marshalled to the service of the central station, gas or electric, a great creative force for the development of further bigger, better business in the lighting field.

It is because this fact has not been generally recognized with the enthusiasm it deserves, and generates, once the idea is grasped, that we see so many central stations, and so many gas lighting companies still going on without any real effort to treat their lighting business seriously. They seem to be content to sell just light—the raw material—instead of accurate illumination as the finished product. Yet we know well that by the systematic application of illuminating engineering, the profits of such lighting business can be immeasurably increased as has been proven in the experience of many cities.

THE PURPOSES OF ILLUMINATING ENGINEERING.

It is worth while, therefore, to consider what really are the actual basic, commercial purposes of illuminating engineering in the central station industry, for instance. There are three purposes:

1. To help develop new lighting business, by converting new customers to the use of electric light.
2. To improve the lighting of present customers and increase its usefulness and value to them; and in this way, gradually to raise the standard of illumination throughout the community and thus, automatically, to increase the company's lighting business.
3. To promote the satisfaction of present customers by giving them better service and more effective lighting that will tend to make them regard more highly the influence and benefits of good illumination; and in this way ultimately to win for the company a greater popularity in the community.

If the practice of illuminating engineering by the sales department of a central station can achieve such results, surely no company should disregard the opportunity. And to prove that the utilization of illuminating engineering has exerted such a broad creative selling force, it is only necessary to cite the definite experience of central stations, who have been awake to its

possibilities. The fact that these companies are operating in communities of different size and under widely varying conditions, is evidence enough that this is a basic policy susceptible to application anywhere. The organization required and the extent to which the work may be developed, of course, depends entirely on the local opportunity and the size of the central station itself.

ORGANIZATION FOR THE WORK.

In the organization of an illuminating engineering department, the objective is naturally to adequately and profitably carry out the three purposes of the work, as enumerated.

In Poughkeepsie, for instance, the Central Hudson Gas & Electric Company employs one lighting specialist who handles all matters pertaining to domestic and commercial lighting. This man lays out lighting installations for consumers and prospective consumers, specifying the proper units, and takes care of all complaints from institutions and large consumers with regard to lighting service.

In Rochester, this work is centered by the Rochester Railway & Light Company in its industrial sales department and there are various men in this department who have become specialists in illuminating engineering work.

In Baltimore, the Consolidated Gas, Electric Light & Power Company maintains an illuminating engineering department which is in reality a selling force for commercial wiring and lighting. Five men specialize in the sale of lighting equipment and the necessary wiring for various branches of service, exclusive of domestic. These are sub-divided as follows: (A) churches, lodges, small stores; (B) offices, banks, large stores; (C) industrial and factory; (D) miscellaneous—not covered by the above and working in any field as conditions require.

In Chicago, the Commonwealth Edison Company has an illuminating engineering division divided into two separate and distinct classes: first, men who do engineering service to all classes of customers; second, men who are specialists in a given line of work, such as industrial lighting. Industrial lighting engineers have a specific section of the city assigned to them for the purpose of soliciting for and recommending improvements in industrial lighting.

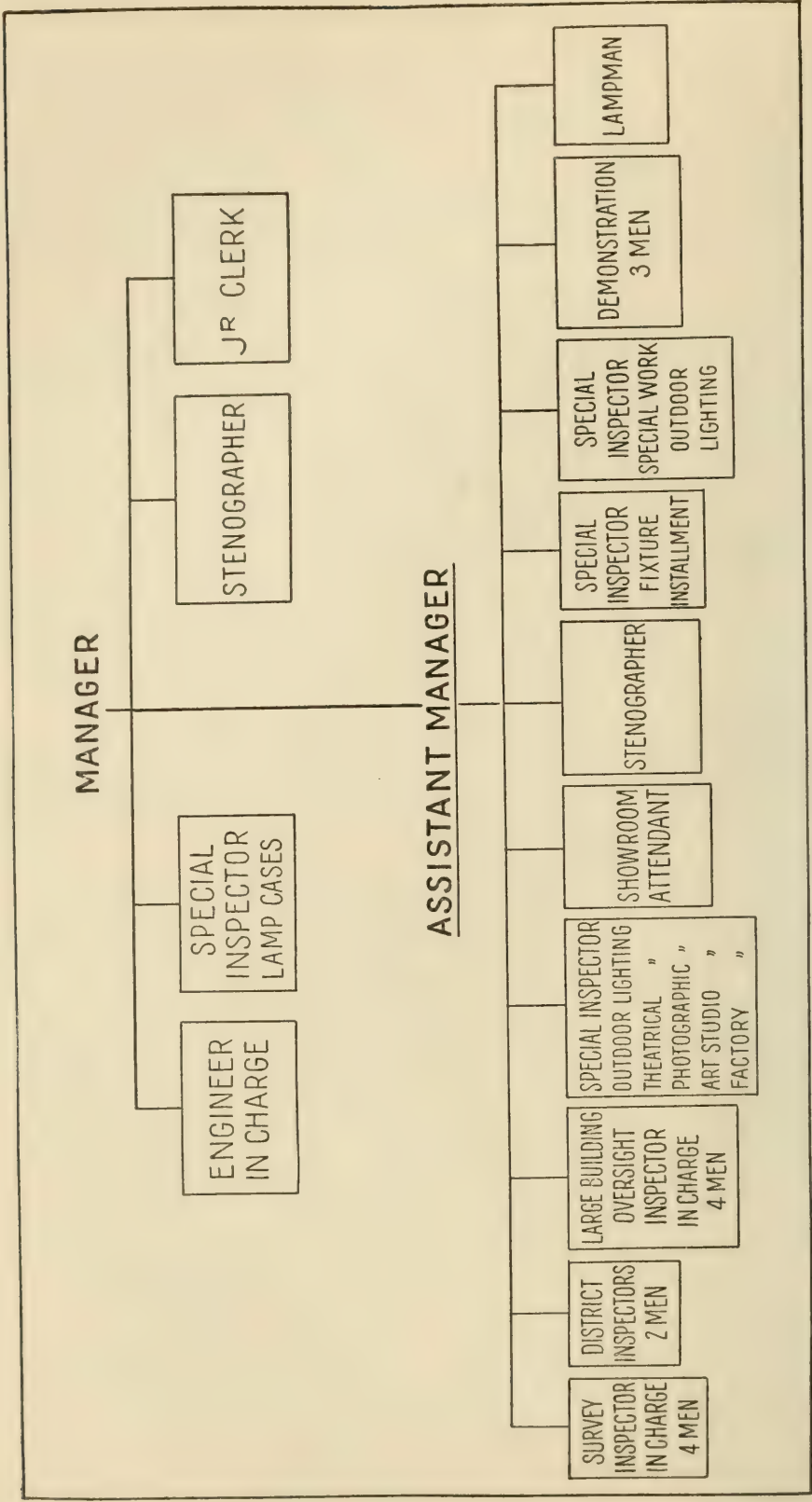


Fig. 1.—Organization of a typical bureau of illumination.

A good example of a broadly organized department is the Bureau of Illuminating Engineering of The New York Edison Company which consists of five sub-divisions, as is shown in the accompanying illustration (Fig. 1). These five divisions are:

(1) Illuminating engineering advice, (2) large building oversight, (3) surveys, (4) lamp questions, and (5) fixture showroom. The following brief description of the operation of these sub-divisions and the reproduction of the various forms employed gives a good idea of the scope and method of their work.

To the first section, inquiries are referred where customers wish advice as to the best methods of illumination for new installations, or regarding more efficient lighting for the purpose of decreasing bills, which necessitates changing of fixtures, glassware or lamps. Such inquiries are referred from all departments of the company and an "Inspector" calls either by appointment or during his regular tour. Where the information can be given immediately, the inspector presents a report to the office on what has been done.

Where the case necessitates a further call due to the fact that more information is required, the report is placed in file and followed up by the Assistant Manager. This second call may be made necessary for the reason that information on lamps, glassware or fixtures has to be secured and this is given either in a letter incorporating the report, or by a personal call. In instances where it is necessary to prepare plans, write specifications and submit estimates, the plans of the buildings are turned in to the office where a tracing is made for the purpose of putting in the wiring and locating outlets. The specifications are written by an engineer in the office, who also secures the estimates. When this has been accomplished, it is also returned to the inspector to report back to the customer.

The Large Building Oversight Division is called upon to investigate installations where private generating plants are operating and advises regarding more economic and efficient methods of illumination with a view to introducing central station service. Where a building has recently been taken over on a contract by the company, a representative of this division supervises the installation in order to keep the consumption within the figures used as a basis for securing this new business. The inspectors working in this division are men specially trained in the economical operation of installations of all types. Their duties are to recommend changes where more efficient type of lamps can be used, or perhaps where a demonstration shows that a change in equipment would ultimately result in a saving for the customer. This necessitates, in some cases, a day and night force, keeping a record of the consumption through hourly readings by meters placed for this purpose, in order that a more detailed oversight may be maintained.

The Survey Division is called upon to make a detailed report of installations by fixtures, lamps and motors. These men have a thorough knowledge of all types and sizes of lamps, and the original figures for the operation of buildings are based on this report, which necessarily has to be accurate for this purpose. The method followed in recording the installation of a given building is by tracing out the various circuits from service entrance, noting the size and type of all lamps, style of fixture used, make and size of all motors and the apparatus which they drive. A grand total of the above is shown, giving the entire current consumption of the building.

The duties of the division handling lamp inquiries are to determine and give information regarding all technical questions in connection with electric lamps. Questions regarding the misuse of lamps, or what is known as "lamp traffic," are also handled. These are cases where customers secure lamps from the company under certain conditions for one address and use them at another. This work also includes the preparation of lamp price schedules. It requires close touch with the lamp manufacturer in order to be posted in the new developments or changes made; also a very thorough knowledge of the company's policy is necessary on both the sale and renewal of lamps to its customers.

Under the supervision of the bureau, also, comes the show-rooms where various types of glassware, fixtures and lamps are displayed. This company does not make a practice of selling fixtures of any kind, but is glad to receive orders which are placed directly on the manufacturers.

HOW A DEPARTMENT WORKS.

Whether the work be entrusted to one man or a dozen, however, the chief aim is the same—to help win new business, to improve present lighting installation and to give better service to the customer. In describing the work his men are doing in Chicago, Mr. Oliver R. Hogue, Head Lighting Agent of the Commonwealth Edison Company, says:

"To win new business, advertising matter of all kinds is sent out to prospective customers calling attention to the free service of our Illuminating Division for the planning of installations on the basis of efficiency and utility. Architects are constantly visited by representatives whose duty it is to make recommendations on new plans and at all times suggest the use of this division in the working out of lighting details. Before the work is done all installations must first be approved by the head of this division, for if the lighting installation is properly planned at the beginning the value of the service rendered by the company is enhanced and the prospective customer seeing the satisfactory installation is very highly impressed.

"In working to benefit the customer salesmen soliciting electric lighting offer the service of the Illuminating Division, which they assure the customer can and is better able to recommend the proper sizes and type of equipment for their particular needs. Newspaper advertising is used to call the customers' attention to the services of this division in improving existing installations, which have become obsolete or inefficient, always calling attention to the fact that their services are free. Photographs of installations which have proved successful are used to substantiate the claims of this division.

"Also where the customer complains of his bills being too high, or when he thinks he is not getting sufficient light, one of our illuminating engineers carefully checks the installation, advising the customers on the sizes of lamps to use and the equipment best adapted for his use, and instructs him in the proper method of using his light. Illuminating engineers have also been called in to pacify complaining customers and by reducing the connected load through the substitution of new for obsolete equipment have been able to reduce bills to such an extent that the customer was more than pleased with the results. Many times the simple fact that the company has sufficient interest in his welfare to take the trouble of having an illuminating engineer call and examine his equipment satisfies the customer that he is getting value received."

In other words, this work of the illuminating engineer is not alone engineering, it is the exertion of a broad psychological influence on the prospect and the customer individually and collectively. As Mr. J. J. Cogney, of the Central Hudson Gas & Electric Company, puts it:

"We are not at all stingy with regard to the services of our lighting specialist. We are glad to have him lay out installations, and make suggestions for improved lighting effects for concerns operating private plants. This practice helps improve the attitude of the owner of the private plant, who feels that our policy is a broad one. It brings us together, and leads him to feel that we are not bad fellows after all—that if he should some day decide to purchase service from us, he would receive proper treatment."

Thus the lighting service propaganda is pioneering in the full sense of the word, as Mr. Frank C. Taylor of the Rochester Railway & Lighting Company points out effectively:

"One of the big advantages of illuminating engineering is that it gets the central station into direct contact with the customer. This is of special advantage because we have found that a man going out on lighting work may find that gas or electricity should also be used there for heating brass furnaces, say, or core baking ovens and for many other purposes. He also may find a gasoline engine

in use, or perhaps some small steam engine which may be shut down and electric power substituted."

EVIDENCES OF ACHIEVEMENT.

The practice of illuminating engineering in the central station field, therefore, is not a burden on the overhead. It is not an expensive service which the smaller company may feel beyond its reach. It is a selling force that continuously proves itself profitable in many ways. The following extracts are quoted direct from letters from companies who are convinced that every dollar spent in this activity is profitable:

1. "A customer who was building a new factory came to us for advice on lighting. We planned correct illumination for several departments and sold and installed the equipment, with the result that his connected load was considerably more than he had originally planned. The results, however, were so good that he expressed his appreciation of our work and assured us that the results more than justified the increase."

2. "A bank, which had been a customer of ours, spoke several times of the poor condition of their lighting and always feared to make a change as they thought it would necessitate increasing their bills. A thorough study was made of their conditions and their own fixtures, which were of excellent construction, were remodeled so that the lighting result finally obtained with indirect illumination was all that they could desire. When the changes were complete it was found that their current consumption was slightly less than they had formerly used with their inefficient equipment."

3. "Another customer in a store had often complained of the service which we were giving him, stating that he was sure that our service was not as good as it had been a few years previously, because he could not obtain as much light as he formerly had when his present fixtures were first installed. We found upon investigation that his lighting equipment was dirty and practically all of his lamps were burning long after their useful life. We sold him a full line of new lamps and gave him advice regarding cleaning his fixtures with the result that he was completely satisfied."

4. "Recently we made quite a notable installation of indirect lighting in a modern reinforced concrete clothing factory, in their sewing machine room. The intensity of illumination in the room was quite high, being about 8 or 9 foot-candles. Their superintendent has stated that he is sure that there has been considerable increase in the work which they are able to do in that room over what they could have done in their old factory under the former lighting conditions. At the same time mistakes and errors have

been reduced materially. They feel that part of this is due to better surroundings, but the greater part of the improvement is due to better lighting conditions."

THE INDIRECT INFLUENCES.

Such definite examples could be quoted without number, but at the same time the indirect results of illuminating engineering work are quite as far reaching and important. One company mentions having improved the lighting of a church, and so impressed the members of the congregation that two factory installations resulted. Another cites a case where after the lighting of a large factory was redesigned, a number of the employees became dissatisfied with the light at home, and called upon the central station to improve it. It is this feature of illuminating engineering work that has developed the careful selection of lamps and reflectors, and has discovered the benefits to be obtained from well designed lighting. It has steadily raised the prevailing standard of illumination. It is assisting in a hundred ways the profitable progress of development. It is a stimulative commercial force that helps the central station build up its market. And whether the salesman calls himself "illuminating engineer" or "lighting specialist," whether there be one man or many working in the city, the effort still will be productive.

All this is shown so clearly, so consistently in incontestable experience across so wide a range of territory, that no utility company, either electric or gas, should longer hesitate. It is time for every one of us to recognize the commercial power of illuminating engineering and to utilize it.

DISCUSSION.

S. B. BURROWS: It seems to me that there are two messages in this paper; one to the company, and one to the men—the salesmen. The value of proper training is not open to discussion, as it seems to me an obvious thing that we must, if we are going to be representatives of a station selling lighting—illumination—we must be trained, and unless those of us who are right next to the consumer will translate these papers into action, it seems to me that they will somewhat fall short of their purpose.

It has been my experience in New Jersey that the men who are

showing their ambition along these lines of educating themselves, are making the best lighting salesmen and therefore the best illuminating engineers.

Z. M. HYER: I realize the advantage to the lighting salesman, of illuminating engineering knowledge. I am not, however, thoroughly convinced that every central station should maintain its own illuminating engineering department. The day is coming when I expect the larger companies will all establish departments of this kind. Our company has given this matter very serious consideration and will no doubt do something along these lines in the near future. The way we have successfully handled our illumination problems is to get the co-operation of the illuminating engineers employed on the job, and work with them. We prefer to work with the illuminating engineer on the job rather than conflict with him. When there is no illuminating engineer employed on the job we usually get the co-operation of the representative of some of the larger lighting accessory companies, usually those men have had considerable practical experience and their information is of more value than our own. The one thing that the central station representatives should do is to try and harmonize all interests on the job when they are working towards one end and that is "Good Illumination," and as soon as he finds that the various interests are working at cross purposes he should get them together and eliminate any misunderstanding.

A. F. BERRY: I would like to ask just how central stations are called in to prepare plans, write specifications and submit estimates, as I notice that one of the authors claims that his bureau does this work. I should also like to know whether they handle and supervise this work on deferred payment plan, or do they give the work to a contractor under competition and have supervision over same?

CLARENCE L. LAW: Mr. Berry refers to where it is stated that "We write specifications and submit estimates." It is meant here that when the specifications are written they are sent out to three contractors for estimates. When these estimates

are secured they are submitted, with specifications, to the customer in order to guide him in placing his contract. The Company may state an amount for which the work could be done, which would be an estimate from experience; however, it does not do any wiring and would not accept an order for the work.

This arrangement applies to both new and remodeled installations.

E. E. WHITEHORNE: I think it is general practice not only among central stations but among gas companies that the salesman in charge of a district keeps in pretty close touch with present customers. He cultivates their friendship, their confidence, and I do not think this practice really can be seriously questioned.

It is certainly good policy if the owner of a private plant comes to the central station asking for certain information or certain assistance, to render that assistance in a friendly fashion, and better the relations with him. It is often by such contact that the opportunity comes to the central station to improve the education of his customer in illuminating subjects, and to increase his appetite for a better service than he is able to secure from his private plant.

I should like to endorse the opinion that has been given, that training for the salesman is essential. Yet to my mind, the basis of the whole business is the commercial purpose, and the commercial purpose in this business is not the securing of the contract, it is the sale of the commodity, the sale of the service which is the objective, and a great deal of harm has been done by taking the name illuminating engineering so seriously that the purpose, the commercial purpose is crowded into the background. Many customers have become confused and have regarded as a mystery, all matters relating to scientific illumination. After all, it comes right down to the commercial purpose, which means enduring satisfaction to the customer, and therefore the consumption of gas or electricity, and the salesman certainly has to have sufficient training and education to be able to make the proper installations which will bring this satisfaction and a saving.

ABSTRACT—RELATION OF THE BUREAU OF STANDARDS TO ILLUMINATING ENGINEERING.*

BY M. G. LLOYD.

Illuminating engineering involves the application of physics, architecture, interior decoration, and the physiology and psychology of light. The work of the illuminating engineer requires the adaption of light from all available sources to all the purposes to which it may be applied. To utilize effectively the available sources, the illuminating engineer must be familiar with the properties of light and its sources, and with the requirements for effective illumination. To know the properties of the sources and of the materials used in equipment, it is essential that quantitative measurements be made.

Many of these requirements are covered in the work of the Bureau of Standards. The Bureau establishes standards for measurement and has custody of the official standards. It investigates possible new standards, improvements in the design, construction and use of standards, and influences affecting their constancy. It investigates methods of measurement and measuring apparatus. It tests the apparatus, the light sources and the materials used in equipment. It determines optical constants and the properties of the eye. It draws up standard specifications for lamps. Its investigation of public utility standards involves many questions connected with electric and gas service and consequently of interest to illuminating engineers.

The quantities in whose measurement the illuminating engineer is interested comprise the total light flux emanating from any source, the density of this light flux or the intensity of the source in any direction, the illumination falling upon a surface, the brightness or luminosity of the surface, the color of light, and the properties of surfaces and of translucent media with respect to the reflection, transmission and absorption of light. The measurement of all these quantities involves, in addition to the more common physical measurements, such as length and area, the additional properties of intensity and color only.

* A paper presented before the Chicago Section of the Illuminating Engineering Society, Chicago, Ill., March 21, 1918.

The standard for intensity of light is the international candle. It is maintained by a series of electric incandescent lamps. The possibility of using flame standards has been thoroughly investigated at the Bureau, and the conditions affecting the candlepower of flames determined. The pentane lamp is a useful application as a working standard for gas photometry of open-flame burners. These advantages do not apply to gas mantles whose candlepower does not vary in the same way with barometric pressure, although affected in a way similar to the open flame by variation in the moisture content of the atmosphere.

In comparing sources having different colors, the flicker photometer has been used as the most satisfactory instrument. Individual differences of observers with respect to sensibility to different colors have been investigated and the characteristics of the normal human eye determined.

Extensive life tests of incandescent lamps are carried out to ascertain whether Government purchases comply with the standard specifications.

The properties of gas mantle lamps have been thoroughly investigated and the effect upon candlepower and efficiency determined under such operating conditions as different qualities of gas, varying pressure, adjustment of the burner, etc.

An extensive investigation of automobile headlights has been made and curves were exhibited giving the distribution of light produced by different forms of headlight lenses.

The operation of gas and electric equipment involves the question of safety which has been made the subject of an extensive study at the Bureau. The protection of the eye from harmful radiation by the use of goggles has been studied and many data obtained for the transmission of colored glass. The Bureau has recently been engaged in helping to formulate safety standards for application in Federal industrial establishments and among these are requirements for illumination.

ABSTRACT—THE RELATION OF LIGHT TO HEALTH.*

BY CHARLES E. DE M. SAJOUS, MD., LL.D., SC.D.

The word "ferment" is steadily being replaced in medical phraseology by the word "enzyme." In the words of Professor Mendel, of Yale, "Enzymes are no longer thought of exclusively as agents of the digestive apparatus; they enter everywhere into the manifold activities of cells in almost every feature of metabolism." In other words, the same ferments, pepsin, trypsin and others which first prepare foodstuffs in the stomach and intestine, for assimilation by the tissues of the body at large, are the same agents which carry on certain functions in the intimacy of the tissues.

Considerable evidence is available to show that these digestive ferments are carried from the alimentary canal to the tissue cells by certain white corpuscles of the blood, in which they are readily found. To these white corpuscles belong the phagocytes, which ingest and digest disease germs. We thus have digestive ferments taking part—along with the oxidizing ferment—not only in the vital processes of each tissue cell, but also the defense of the body against disease.

Prevost's theory of mobile temperature equilibrium is now known to apply to radiant heat as well as to heat energy derived from other sources. It is simply that if two bodies of different temperature are placed close to each other, the warmest of the two will lose heat by emitting radiant heat which the colder body will take up until the temperature of both is equalized. Briefly, the skin absorbs radiant heat when the cutaneous temperature is lower than that of the radiations received, up to certain limits (influenced by the perspiration and other factors) and the temperature of the tissues of, and beneath, the skin is thus raised.

The penetration of radiant light through the tissues when long wave lengths characterize the rays, is considerable, that of red rays for instance, exceeding one inch. Careful experiments by Rollier showed that solar rays could penetrate the hand and forearm and also, under favorable circumstances, the entire chest.

* A paper presented before the Philadelphia Section of the Illuminating Engineering Society, Philadelphia, Pa., May 17, 1918.

How does light energy influence the vital process of those tissues and contribute to the defense of the body against disease? Charcot, the French neurologist, as far back as 1859, urged that we should distinguish between the purely chemical effects and those produced by heat. In the present connection we probably are dealing with a process in which the chemico-physical effects credited to oxidizing ferment I have termed "adrenoxidase" and heat both take part, particularly near the surface.

There exists immediately under the superficial tissue a great system of small interwoven canals which, so to say, act as sewers of the tissue cells. They serve not only to carry off, but also to purify the fluids received from those cells by breaking down, as far as possible, the wastes and detritus that they form while carrying on the process which constitutes their life. These channels are interspersed with glands that contain phagocytes, *i. e.*, cells of the type that destroy, by means of their digestive ferments, disease germs and other harmful substances that the small canals carry to them from every direction. This system of lymph channels and glands, known as the lymphatic system, is a prominent weapon of defense. Everyone has seen lymph, a whitish viscid fluid, collect on abrasions, and also enlarged glands on the neck of children. These latter are enlarged lymphatic glands trying to destroy bacteria from some source, the tonsils, adenoids, etc., thus preventing general infection.

The beneficial influence of sunlight is readily accounted for when we take the lymphatic system into consideration in addition to the tissue cells, in view of the effect of light energy as manifested by its radiated heat. Indeed,—and this is the dominating factor in the process—the ferments of both kinds previously referred to, those which promote tissue oxidation and those that digest and destroy bacteria and organic poisons become increasingly active as the heat to which they are exposed is increased, and we obtain as result an increase of both vital activity and defensive aggressiveness.

This *increased efficiency of ferments under the influence of increased temperature* is the method adopted by Nature, according to my own viewpoint. It explains the process we term "fever," long deemed an enemy, but in reality a defensive function calculated to destroy poisonous substances or germs that have found

their way into the body fluids and cells from a focus somewhere, either in the superficial or deep tissues. In the course of fever, the germ destroyers, or phagocytes, are not alone at work in the blood stream, but the whole internal lining of the bloodvessels themselves is made up of these germ destroying cells. Again, the lymphatic vessels which act as drains for the tissue cells, we have seen, afford additional aid in the defensive process by means of the multitude of phagocyte-laden glands through which the serum obtained from the blood by the tissue cells must pass before it is returned to the circulation.

Of course, abnormally high fever, *i. e.*, fever above 104° F., for instance, may become dangerous in the sense that the very digestive ferments which have their purpose to defend, become too active and begin to digest not only the red blood corpuscles, a process physicians term "hemolysis," but also certain tissues, a process known as "autolysis." To offset these morbid effects of excessive radiation during hot weather, the skin protects the body by perspiring; the water which moistens the skin, by evaporating, keeps the surface temperature within normal limits. The cool baths physicians employ in the treatment of typhoid fever, have the same end in view; they keep the fever within safe limits.

On the whole, the relation of light to health may be summarized, in view of the few data submitted, by the statement that it is intimately bound up with the perpetuation of life, whether the tissues be normal or diseased. It tends to sustain health by promoting, as radiant energy, the activity of the oxidizing ferment adrenoxidase, which sustains the oxidation of tissue cells, an essential function of their life. It tends to defend the cell, when endangered by certain germs and poisons by enhancing through the heat energy developed, the efficiency of the defensive ferments which submit these harmful agencies to digestive destruction.

ABSTRACT—NOTES ON ILLUMINATION IN STORES AND FACTORIES.*

BY FREDERICK J. PEARSON.

An absolutely uniform lighting system in an establishment is inferior to a fairly uniform general lighting system supplanted by special lighting where necessary. Artificial lighting is used only for a small portion of the 24 hours and should be intensified to stimulate production. Efficiency, while important, should not always receive consideration to the exclusion of other factors which may result in greater satisfaction, increased sales in a store, etc. Reproduction of a lighting system merely because it was found to be satisfactory elsewhere, without considering the local conditions, may lead into error. Local conditions must govern design. In a store, a uniform general lighting system for all departments should be used as far as practicable in order to simplify maintenance. As few large units as practicable should be used in order to reduce the initial and operating costs. The fixtures should be of simple outline and in harmony with the surroundings. Fairly dense diffusing globes with gas filled tungsten lamps are desirable. Show case lighting is rather unsatisfactory because of the poor service from the special lamps used. It is, however, necessary to light show cases locally. Show window lighting still suffers to some extent from exposed lamps.

Light conditions in most factories are poor. Good lighting increases production just as it increases sales in a store. Increases of illumination intensity from 6 to 10 foot-candles have increased the cost of lighting by only 1 per cent. and have been found to promote sales by 6 or 7 per cent. Increase of lighting cost of 2 per cent. in one installation was reflected in an increased factory production of 10 per cent. In fact improved lighting is one of the greatest of dividend producers whether in the factory, the store or the office. We are still far below the saturation point in artificial lighting intensities.

In discussion, Prof. E. H. Freeman pointed out that the real measure of illumination effectiveness is the ratio between results

* A paper presented before the Chicago Section of the Illuminating Engineering Society, Chicago, Ill., April 18, 1918.

secured and cost. In factories it is the relation of production to cost of lighting; in stores it is the relation of sales to cost of lighting.

Mr. J. R. Cravath questioned if local show case lighting is necessary.

Mr. O. L. Johnson referred to the difficulty in getting store and factory managers to appreciate the importance of good lighting which can be obtained only by the use of good equipment, well installed, with due respect to the local conditions. He inquired concerning the practice in department store lighting of adapting the lighting to changes among departments, and asked as to the effect of different lighting intensities on different departments from one to another of which shoppers might go.

Answering questions, Mr. Pearson made the following statements:

Show case lighting, although troublesome, is a necessity, because goods in cases cannot be lighted properly from a general illumination system. Merchandise sells better under light of higher intensity. In factories the choice of enclosing globes or reflectors must depend upon local conditions. Both are used in particular cases with success. It has been observed that intensified lighting results in greater activity, more enthusiasm and better sales service. Under daylighting there are on bright days fewer accidents, fewer discharged people, less dissatisfaction among employees. There is also a larger production in the factory and better workmanship. The difference between bright days and dark, cloudy days is really surprisingly large. In artificial lighting, with 7, or 8, or even 9 foot-candles, where formerly 6 were employed, better results have been obtained. Since increasing the illumination intensities employees and customers have both shown more enthusiasm, interest and activity. In the factory 6 or 7 foot-candles of general illumination is used, supplemented by local lighting. In dye houses and bleacheries, 12 to 15 foot-candles is the intensity adopted.

ABSTRACT—PHYSICS OF THE WELSBACH MANTLE.*

BY H. E. IVES.

The investigation here described, insofar as it deals with the radiatory characteristics of the incandescent mantle, constitutes chiefly an extension of the work of Rubens on the thoria-ceria mixtures to a large family of such combinations. It exhibits the Welsbach mantle of commerce simply as one of a group of possible combinations of radiatory materials, behaving according to the same general laws, but remarkable among them for the degree to which the characteristics of selective radiation are exhibited.

A more detailed study has been made than any heretofore on the behavior under various conditions of the absorption bands to which the enhanced visible radiation of the more efficient mantles are due. While no explanation has been found for the occurrence of the visible absorption bands of ceria—a question to be solved only by a more intimate knowledge of the structure—the information learned as to the conditions under which they appear and disappear has made possible a rather complete explanation of some long standing enigmas, notably that of the different behavior of the mantle in flame and cathode discharge heating.

Another line of investigation has here been taken up apparently for the first time in any detail, namely that of the energy relations holding with flame heating of radiating materials. As a result of the study it has been possible to fix with some definiteness the possible attainable efficiencies of gas light production by present methods. These, while low, are still many times now reached.

* A paper presented before a joint meeting of the Franklin Institute and the Philadelphia Section of the Illuminating Engineering Society, Philadelphia, Pa., January 10, 1918. The full manuscript may be found in the *Journal of the Franklin Institute*.

ABSTRACT—OFFICE LIGHTING.*

BY WARD HARRISON AND J. R. COLVILLE.

The authors stated that the problem of office lighting was fundamentally one of providing the best illumination for the sustained vision of flat surfaces in horizontal or slightly oblique planes as contrasted with lighting for the perception of objects in their three dimensions, so important in the industries and the arts. Illumination intensities of 4-8 foot-candles were mentioned for offices, and 8-12 foot-candles for drafting rooms. The use of the daylight lamps was suggested in the offices where daylight must be supplemented by artificial light during a considerable portion of the time. Emphasis was placed upon the desirability of low ratios of brightness between visible light sources and their surroundings. Direct, semi-enclosing, semi-indirect and indirect units were classified as to their relative desirability from the standpoints of glare, specular reflection and shadow. The proper field for each type of unit was taken up. Co-efficients of utilization for the various equipments and proper spacing ratios were included. The application of individual lamps in the lighting of private offices was also taken up.

DISCUSSION.

Discussions of this paper were made by Messrs. Hyde, Regal, Colville and Harrison. Dr. Hyde mentioned a special indirect desk lamp which proved very useful under certain conditions, and inquired as to the best ratio of wall brightness to brightness on the work. Mr. Regal discussed the question of density of glass where used in indirect lighting and asked what means were available to the customer for judging the density. Mr. Colville points out the desirability of proper location of desks with respect to the daylight conditions. Mr. Harrison, in closing, remarked that a rough comparison of the density of any two semi-indirect units can be obtained by holding them up to the light.

* A paper presented before the Pittsburgh Section of the Illuminating Engineering Society, Cleveland, Ohio, December 14, 1917.

For accurate quantitative values a photometric test is necessary. Mr. Harrison recommended that the brightness for the side walls should not exceed $\frac{1}{4}$ or $\frac{1}{5}$ that of a sheet of white paper lying on the desk. He mentioned that the upper limit of desirable intensity for office illumination had not been reached, that it might be in the neighborhood of one hundred foot-candles.

ABSTRACT—TIMELY ASPECTS OF LIGHTING.*

BY M. LUCKIESH.

The opening remarks were devoted to emphasizing the importance of light in warfare and the influence of lighting in the economics of production. A variety of phases were touched upon including searchlights, special problems of colored light such as fog-penetration and short-range lights, signaling, and lighting for various war activities. The importance of good lighting in production was emphasized and attention was directed to lighting as a great factor in the tremendous developments of the present age. Much of this impetus was attributed to continuous lighting, day and night, which makes the output of factories continuous. Mr. Preston S. Millar's paper on "Lighting Curtailment" was abstracted with the aim of emphasizing the fact that there are better ways of saving coal than by curtailing lighting. The broadening of the field of the lighting expert was revealed by discussing several fields of lighting. For example, camouflage is one of these and, in discussing this and other examples, it was shown that those who are experts upon light, color, lighting, vision, and the appearance of objects as influenced by lighting, finds fields in which they can render valuable service. The address closed with a view of the future in which were pointed out the fields of lighting which have not been attacked in the best manner by those who are responsible for lighting. These remarks were directed chiefly toward the subtler problems of lighting in which esthetics (or more broadly, psychology) and ordinary illuminating engineering meet. An endeavor was made to show how the fixture-dealer and some others who come in contact with the consumer, were not rendering the best lighting service.

* A paper presented before the New England Section of the Illuminating Engineering Society, Boston, Mass., May 21, 1918.

ABSTRACT—THE TRAINING OF A LIGHTING SALESMAN.*

BY CHAS. A. LUTHER.

The qualifications necessary to successful salesmanship are outlined. The lighting salesman, if he represents a lighting utility, has an added responsibility to cultivate good relations between the public and his company, and is obligated to consult the interests of the customer to perhaps an even greater extent than is a salesman in most other lines. Only by thus consulting the customer's best interests can he serve his company to advantage. To do this a fair general education must be supplemented by a thorough grounding in the principles of illumination and the salesman must be well posted in regard to the technical and performance data of his own and competing systems of illumination.

The lighting company can assist materially by holding regular meetings of salesmen before which problems will be discussed, appliances demonstrated and principles illustrated. Also at such meetings all new devices and useful new information can be placed before the salesmen. It may be advantageous in some cases to take the salesmen through an educational course in illumination. Where this is done, these meetings should be handled as students classes, the meeting room being appropriately equipped. Debates as to the relative merits of their own and competing equipments are sometimes of value.

* A paper presented before the Chicago Section of the Illuminating Engineering Society, Chicago, Ill., June 13, 1918.

ABSTRACT—LIGHT: FINE ART THE SIXTH.*

BY MARY HALLOCK-GREENEWALT.

This presentation had to do with the use of light as a fine art, and its analogical co-relation to music. It included demonstrations of piano numbers with a co-ordinated atmosphere of light, *with* and *without* color. The impossibility of anyone not by training an artist to develop an art was dwelt upon and credit given the engineering field for the work which made this development mechanically possible.

From the many attributes which go to make up this, as any art, the speaker separated the dynamics of the dark and light from such other attributes as "time" and "color" and showed that here psychological proof existed of the emotional effect on the individual of grades of brightness from the absolute dark to the highest light, which effects could be said to have their counterpart in the shadings of tone as these affect the individual. Since brightness stimulated the pulse rate of the human being, as well as the creature, since the pulse of sub-conscious analogy impressed its time variations on the rhythmic expression of the being, so a direct scientific contact could be established between brightness and the time rates of music but only as the "pavillion covers all the merchandise."

It was on March 15, 1911, that the speaker first combined the two effects intensifying the pleasure and feelings derived through the ear by that simultaneously presented to the eye.

Drawings showing mechanical means for such plastic use of light as would be capable of following the dynamics of sound in a manner as subtle as the underlying physiological perturbations of the heart and lungs were shown; and announcement made of applications for patents.

The end of the lecture was devoted to argument relegating the analogies of color and sound to such categories as quantity, quality, extension, and in its aesthetic sense only, weight.

* A paper presented before the Philadelphia Section of the Illuminating Engineering Society, Philadelphia, Pa., April 20, 1918.

SYNOPSIS OF POPULAR LECTURES CIRCULATED BY THE ILLUMINATING ENGINEERING SOCIETY.

NOTE: The following present summaries of the three popular lectures prepared by committees and approved for circulation by the Council of the Society. Complete manuscripts of these lectures with accompanying slides may be obtained for presentation upon application to the general office. It is the purpose of these lectures to enlighten the public regarding good illumination.

STORE LIGHTING.

The lecture on store lighting is a very thorough treatment of the application of artificial illumination to the store. It deals not only with general interior illumination but also takes up show-case lighting, show-window lighting, and store exterior lighting. The lecture is illustrated with 62 slides which serve to bring out very clearly the different points as they are discussed throughout the talk.

The opening part of the lecture is given to a discussion of the importance and value of good lighting to the merchant, bringing to mind the fact that the cost of light is extremely low when its value as an advertising agent is considered.

In taking up the fundamental principles of store lighting, light intensity, color rendition, light diffusion and distribution, avoidance of glare, and the proper location of light sources are discussed in a very interesting manner. The outstanding characteristics of good lighting, it is pointed out, are that there be enough light to permit comfortable vision, and that this light be properly diffused and distributed so that no annoying glare or undesirable shadows are present.

The three general systems of lighting and the reflector equipment suitable for each are discussed with reference to the classes of stores for which each system is most available. Open reflectors, semi-enclosing, and totally enclosing units may be used where direct lighting is desirable; inverted translucent bowls find application with the semi-indirect system where part of the light is transmitted directly and the remainder is reflected to the ceiling and thence down into the room.

The subjects of show-case lighting and show-window lighting are shown to be important phases of store lighting. In both cases, the fundamental requirement is to project light on the displayed goods and not into the eyes of the observer. This, in most cases, necessitates the concealment of the light sources.

In taking up the last phase of store lighting, that of lighting the exterior front, the important point brought out is that such lighting should not interfere with the show-window lighting. Among the various means, that of flood-lighting the store front is the most recent.

In conclusion the point is brought out that good lighting is worth dollars and cents to the merchant. Poor artificial lighting, far from being an economy, is a liability.

THE LIGHTING OF THE HOME.

"How shall I light my home?" is the theme of this lecture and the answer is given in clear, non-technical English. The suggestions can be applied with gas or electric lighting service and the field for the presentation of the paper is consequently unlimited. An outstanding feature is that no hard and fast rules for the proper illumination of the home are given, but the reader, or listener, is shown how initiative may correct existing lighting evils and convert mediocre lighting into good lighting.

Before entering into the subject proper, a general discussion is given of the more important of the fundamental principles involved. Among these are: the description of the functioning of the eye; the physical conception of light and color, with a demonstration of the color of a number of artificial illuminants; the definition of glare through illustrative examples, the cause of glare and how proper design and equipment may minimize it. The selection of fixtures to harmonize with the room furnishings is pointed out. The need of a reflector to secure an efficient distribution of light is explained. The causes of a flickering light are mentioned. Cleaning the lighting equipment is brought to the attention.

With the proper location of outlets, the question of the direction of light can be more easily handled. Lighting units are divided

into three general classes according to their influence upon the direction of light. Each class, or system, is illustrated and the merits of each pointed out.

Attention is now directed to the practical application of the principles mentioned in the preceding part of the lecture. The idea is used of having the discussion so planned that the illumination is consecutively explained to the reader, or listener, as he would encounter them on a trip through the home. Thus, the porch lighting is followed by the reception hall lighting and this by the living room or library lighting, and so on. In discussing the illumination of any particular room or place, illustrations are shown of several equally good types of installations.

Some time is spent upon the lighting of the library or living room and the effect of different means of lighting is shown by photographs. The value of portable floor and table lamps in the improvement of the appearance of the room is shown. Considerable discomfort and damage to the eyes could be caused by glare in these rooms because the occupant may remain in about the same position for considerable time.

The dining room lighting is discussed from the standpoint of the advantages of the several systems usually employed.

The lighting of the kitchen should be more utilitarian than decorative. Here the light sources should be mounted high. The same considerations hold in the lighting of the pantry. The laundry should use moisture-proof units.

A high intensity of illumination is not required in the bedroom and indirect units supplemented with brackets or small lamps for the dressing table give very pleasing results. The closets may usually be sufficiently lighted from one ceiling outlet or, if shallow, they may receive enough light from the adjoining room. The bathroom, having light colored walls and ceiling, is well adapted to indirect lighting.

In the basement, lamps are placed wherever special lighting is required, such as, at the foot of the stairs.

With all systems of lighting, some thought should be given the placing of switches for the control of the lamps.

Fixtures and glassware are discussed at some length. Glassware is especially important because the effectiveness of the

system depends upon the suitability of the glassware selected. A general discussion is given of the adaptability of various types of reflectors to the illumination of the home. Table lamps are taken up in this connection.

In conclusion, it is said that good residence lighting is common-sense lighting, a combination of a few fundamental principles with a sense of harmony and artistic taste. When doubt exists, the advice of specialists should be sought.

Accompanying the lecture are forty-two slides which cover the wide range necessary for such a subject. Among them are a cross-section of the eye, the spectrum of daylight as obtained from a prism, porch lighting, and the improper and proper lighting of the rooms in the residence, as well as a number of cartoons to hold the audience.

PROTECTIVE LIGHTING.

This lecture treats of the use of light as a means of defense against damage to the industrial and military machinery of the country resulting from sabotage and acts of enemy agents in general. The treatment of the subject is popular throughout. The opening paragraphs dwell on the need for protective lighting. There then follows a brief discussion of the principles of illumination that must be observed if a satisfactory installation is to be obtained. These principles are illustrated by lantern slides. This part of the lecture serves to pave the way for an intelligent understanding of the discussion of actual installations which follows.

The main body of the lecture consists of a number of illustrations of installations, each of which is discussed separately and its good and bad features pointed out. The lecture conforms with the recommendations of the Committee on War Service of the Illuminating Engineering Society on protective lighting.

The authors have aimed to keep in mind the viewpoint of the popular audience and for that reason have avoided going too far into the details of the subject. The general impression which it is hoped to convey to the popular audience is—first, that there is such a thing as the use of light as an effective means of protection; second, that there are right and wrong ways of installing

lighting for this purpose and to point out in a general way what is right and what is wrong; third, that expert advice is available and that the services of experts should be sought if an extensive system is to be installed.

The lecture can well be presented in an hour's time; it is illustrated by thirty-four lantern slides.

The above lectures were prepared by the Committee on Popular Lectures. All of these lectures have been reviewed by the Committee on Papers. The Society is indebted to the following sustaining members for their co-operation in the manufacture and up-keep of the slides illustrating these lectures:

The Edison Lamp Works.

The United Gas Improvement Company.

The New York Edison Company.

National Lamp Works.

National X-Ray Reflector Company.

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TRANSACTIONS OF THE Illuminating Engineering Society PART II -- PAPERS

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WARTIME LIGHTING ECONOMIES.*

COMMITTEE ON WAR SERVICE OF THE ILLUMINATING
ENGINEERING SOCIETY.

Every citizen can assist the Fuel Administration in its efforts to conserve the coal which must be saved if the war ability of the nation is not to be impaired. Principally this may be done by adopting good practice in house heating. To a lesser but important extent it may be done through careful economies in lighting.

This guide to economies in lighting has been prepared by the Committee on War Service of the Illuminating Engineering Society¹ at the request of the Fuel Administration extended through the National Committee on Gas and Electric Service.

It is the patriotic duty of each citizen to see to it that no fuel is wasted in his service. The technical guidance here offered should make it possible for each to adopt lighting practice which will conserve fuel without impairing public welfare or diminishing useful accomplishment.

The following simple rules lead to the elimination of waste in lighting, both by limiting the use of artificial light to the minimum necessary number of hours per day, and by promoting the most efficient use of artificial light during those hours.

ELIMINATION OF WASTE IN LIGHTING.

Do not light lamps when sufficient daylight can be had.

Extinguish lamps when leaving a room unoccupied even for a few minutes.

* A paper presented at the twelfth annual convention of the Illuminating Engineering Society, New York, October 10, 1918.

¹ Underlying the accepted principles of illumination are requirements for safety, conservation of vision, aesthetics, comfort, convenience and economy. The Illuminating Engineering Society is committed to the preservation of these principles and to their application in lighting practice in the public interest. A number of recommendations here presented, particularly those advocating decreased use of light, are calculated to save fuel rather than to bring about most desirable illumination conditions. These are to be regarded solely as a war measure, justifiable in the present emergency, but otherwise not to be approved.

- Use pilot flames on gas lamps. They facilitate relighting and leave no excuse for failing to extinguish lamps when their light is not needed.
- Do not use lamps which contribute merely to decoration.
- Do not use more lamps or larger lamps than necessary.
- Do not use all the lamps when part of them will suffice.
- Use single large high efficiency lamps rather than a number of small lamps.
- In halls, bathrooms, etc., turn down gas lamps when full light is not needed. Use electric turn-down lamps or turn-down devices.
- Do not use electric lamps of the carbon filament type where the more efficient tungsten filament lamps can be employed.
- Do not use open-flame gas burners where the more efficient mantle burner lamps can be employed.
- Do not use blackened electric lamps or broken mantles or discolored chimneys. New lamps are more efficient.
- Do not use indirect or semi-indirect lighting fixtures in conjunction with dark ceilings which absorb a large part of the light.
- Use light colored reflecting surfaces (ceilings, walls, etc.) wherever practicable. These reflect much of the light and make it possible to employ fewer or smaller lamps.
- Clean lamps, shades, globes, windows, etc., thoroughly and often. Dirt absorbs light.
- Consult the lighting company for advice as to best lighting practice and latest devices.

DAYLIGHT.

- Use daylight during the war in preference to artificial light wherever and whenever possible.
- Raise the shades to let in the daylight instead of lighting lamps.
- Arrange window shades to admit maximum daylight when desired. A good arrangement is to have two rollers at the middle of the window, one drawing up and the other down.
- Ceilings and upper walls should be light colored and clean. Light colored surfaces reflect five to ten times as much light as dark surfaces. They conserve both daylight and artificial light.
- Refracting or diffusing glass in windows helps to spread the light to distant parts of the room.
- Whitened surfaces on building exteriors (especially about courts of high buildings) give more and better daylight in opposite buildings.
- Keep windows and skylights clean. Dirty windows may absorb half the daylight.
- Dust window screens frequently. Remove them as soon as the insect season is passed. They absorb one-third of the daylight.
- Carry out operations requiring strong illumination near windows where plenty of daylight is available.
- Arrange machinery, furniture, etc., so that daylight falls on objects to be seen—not on the eyes.

The considerations underlying these rules for economical lighting are as follows:

Fuel Consumed in Artificial Lighting.—The total coal output of the country this year is estimated at 700,000,000 tons. About $2\frac{1}{2}$ per cent. of this is consumed in the production of artificial light. Electric lighting requires about 12,000,000 tons. The net consumption of coal in gas lighting is smaller (to which, however, a large amount of oil is to be added).

Relative Efficiencies of Various Lamps.—Most artificial light is produced by consuming fuel. Whenever a lamp is extinguished, the consumption of fuel is diminished. A small lamp consumes less fuel than a large lamp. Inefficient lamps require more fuel for a given production of light than do efficient lamps. The gas mantle lamp will produce five times as much light as the open-flame burner for the same consumption of fuel. An intelligent choice of lamps therefore makes it possible to reduce the consumption of fuel.

Shades and Globes for Lamps.—Modern lamps are so brilliant that they may injure the eyes if used without protective equipment. Shades and globes conceal them from view, soften and diffuse the light, and, where desired, redirect a considerable part of the light in the direction needed. Shades and globes never increase the total quantity of light, but an efficient reflector will usually increase the light where it is needed. With such a reflector a smaller lamp may suffice, thus saving coal. The advice of the lighting company should be sought when selecting such equipment.

Painting.—As a rule, at least one-half, and sometimes practically all, of the light utilized in interiors is received by reflection from walls and ceilings. Good light tinted paint when fresh rarely reflects more than one-half of the light which falls upon it. The proportion of light reflected from good white lead and oil paint under average conditions diminishes by about 10 per cent. a year. The same is true of calcimine and similar coatings. It is apparent therefore that there is an opportunity for improving lighting efficiency through the employment of the best finishes for ceilings and upper walls. Painting white ordinary light tinted surfaces may increase the light reflection by as much as 50 per cent. Therefore in order to save fuel in lighting, wherever it is practicable paint ceilings white; employ light tints for

the upper parts of walls; and use paint that is non-porous and easily cleaned.

Extravagant Lighting.—Extravagance in wartime is unpatriotic. It involves application for selfish purposes of money and energy necessary to winning the war. Lighting in excess of that which is necessary, and lighting for needless display or decoration at such a time is extravagant.

Display Lighting.—The question of illuminated advertising display is a part of the larger question of general advertising practically all of which involves consumption of fuel. The desirability of curtailing lighting of this character would appear to depend upon the necessity of reducing advertising in general.

Proper lighting display has a place in maintaining the morale of the people no less important than amusements and recreation. Display lighting also has a certain utility in providing necessary illumination. General and needlessly extensive display and inefficient methods of lighting display under present conditions are extravagant. In planning lighting of this character every economy of energy not inconsistent with reasonable effectiveness of the lighting should be sought.

Fallacies in Lighting Economies.—Removing reflectors or shades from lamps in order to "get more light" defeats the object. The raw light from glaring bare lamps is less effective than a smaller quantity of reasonably diffused light not exposed to the eye.

Attempting to economize by reducing the number of lamps or by using smaller lamps *indiscriminately* is unwise. In nearly every case ample illumination is essential to useful accomplishment. The most successful conservation is elimination of waste of light, not reduction of use of light.

Where Not to Save Coal.—In wartime human energy and financial resources are to be conserved as well as fuel. Except in the greatest emergency it is unwise to save a little coal at the expense of waste of labor or impairment of health or menace to the safety of the public. Coal saved through the improvement of lighting equipment is clear gain. To diminish lighting standards in industrial plants, offices and other places where accom-

plishment depends in part upon vision is to reduce accomplishment or output. In such places, therefore, lighting should not be reduced. On the contrary, an increase in the standard of lighting may be the truest economy and in the best interests of the nation. The liberal use of light for protection of important property, munition factories, public works, etc., is likewise in the public interest, and under present circumstances no attempt should be made to save fuel through the reduction of such lighting.

Curtailement a Local Matter.—In an acute local fuel situation an absolute lack of fuel may result in largely curtailed activities. If there is no fuel, industry must cease. Such a critical situation obviously demands radical curtailment of lighting beyond anything which is contemplated for general adoption.

In certain localities in the height of winter there may be a power shortage due to abnormally taxed generating capacity. This likewise may necessitate local lighting restrictions of a more extreme character.

In either event, when such a situation occurs, the problem is a local one, the handling of which must be governed by the particular circumstances.

Specific Applications.—Intelligent application in any lighting installation of the suggestions contained herein will result in appreciable saving of fuel. In some classes of installation certain of these methods of saving have more conspicuous application than others. In the following pages these more evident applications are described.

STORE LIGHTING.

The amount of fuel consumed in store lighting is of sufficient magnitude to make a consideration of possible economies worth while. Waste is usually due to causes rather easy of correction without involving a decrease in the effectiveness of the illumination.

Economies may be effected by:

1. Eliminating excessive illumination.
2. Avoiding the burning of lamps when not actually needed.
3. Saving the light wasted by dirty glassware, dark walls and ceilings and inefficient equipment.

I. Illumination in stores should be only that necessary to enable customers to see comfortably and plainly even where the closest discrimination is required to the end that they may make selections and judgments quickly and satisfactorily and to enable salespeople to perform their duties quickly and easily. The degree of illumination suitable for any particular case may be determined by actual trial through the use of more or fewer lamps or of lamps of greater or lesser power.

II. Lamps should be so controlled that only those actually needed will be in use at any time. In small stores this may be accomplished by controlling each individual lamp or cluster of lamps at the fixture. In larger stores the lamps farthest removed from the windows should be on separate circuits being switched on first as daylight diminishes, the outer lamps being turned on later as necessary. In all cases the greatest practicable use should be made of daylight.

III. The loss of artificial light due to dirty glasswares and dark or dingy ceilings and side walls ranges from 30 to 50 per cent. and may be avoided by renovation at necessary intervals. Ask your lighting company.

Large lamps are usually more efficient than small lamps and where practicable installation should be altered to consist of the fewest lamps from which uniform illumination may be obtained under the conditions of use. Show windows should be lighted by lamps with efficient reflectors; by the use of these it is often possible to save from 25 to 50 per cent. of the energy required for illumination without impairing the illumination in the window. Under no circumstances should bare lamps be visible from the street as this renders the eye less sensitive and makes a higher intensity necessary in the interior of the store, thus defeating the purposes for which these economies are urged.

HOTEL LIGHTING.

It is suggested that waste in guest rooms be reduced to a minimum by having a notice, probably a card, placed near the door reading,

U. S. F. A.

SEAL

"It is requested by the U. S. Fuel Administration that you kindly turn off the lights when leaving the room, and help save fuel."

All employees of the hotel especially the housekeepers having charge of the guest rooms should be cautioned to see that lamps are not left burning when rooms are unoccupied and that when rooms are being cleaned only necessary lights are turned on. Bell boys should be instructed to turn on only the main or overhead lamp when showing the guest his room.

In dining rooms where two systems of lighting are in use, such as overhead and table lighting, one of the two should be reduced or eliminated entirely. Where overhead lighting is sufficient, table lamps solely for decorative effects should be done away with.

In public rooms such as cafés, lobbies, writing rooms, etc., the illumination should be reduced to a point consistent with comfort. All decorative lamps, around mirrors or on brackets, etc., not absolutely essential to produce illumination of a sufficient intensity to avoid a feeling of undue depression or gloom should be eliminated.

While it is important as a measure of safety to keep stairways, passageways, and halls adequately illuminated, it should be remembered that hall lights burn long hours and in cases where convenience or safety is not menaced reductions as to number and size of lamps must be made.

Service rooms where lamps are allowed to burn constantly should receive consideration, for example in large barber shops where only a few chairs are in use lights over the other chairs should be turned off. In the kitchen only those parts of the room

actually being used for preparation of food, washing the dishes and the like should be lighted.

HOME LIGHTING.

What can be done in the home to conserve fuel? To answer this question let us ask what things in the home are done by means of fuel. Well, heating, cooking and lighting are mainly done by its use; and either directly or indirectly this fuel is mainly coal. So that to conserve fuel in any of these three uses there are two methods to be considered: (1) To make sure of the efficiency of the appliance used, and (2) To limit the time of its use to a minimum.

It may not be generally known that the percentage of fuel used in the homes of Americans for these three purposes is about as follows:

For heating (house and water).....	87 per cent.
For cooking	11 per cent.
For lighting	2 per cent.
<hr/>	
	100 per cent.

Our specific purpose here is to consider the conserving of fuel in home *lighting*.

Home lighting is by means of *two kinds* of *light*—*Natural* or daylight, and *Artificial* light. To properly use the former is to aid in conserving the latter, which requires coal.

At periods near dawn and near dusk, and during the heavily clouded days we supplement daylight by artificial light; and many times we do this unnecessarily because we do not make maximum use of the daylight at hand.

Daylight.—(A) Keep window panes cleaned; as much as half the light may be absorbed by thick films of dust.

(B) Keep insect screens dusted; when repainting use light colored paint instead of dark, and do not paint the mesh closed; or else use galvanized wire which is light in color and durable. Also, remove the screens as soon as the need for them has passed. Many screens stop one-third the light.

(C) Housewives will be reluctant to give up, even to a degree, their use of lace curtains; but some minutes of artificial lighting may each day be saved by a judicious use of these during very bright periods only.

In short, use daylight wherever possible in place of artificial light:

EARLY TO BED AND EARLY TO RISE
SAVES OUR BOYS, FUEL AND CARGOES AND LIVES.

Artificial Light.—It cannot be said, in general, that our homes are *overlighted*; but as first stated above, it is true that many of them use light inefficiently, and many of them are lighted *overtime*. It is desirable, therefore, to correct both of these wastes, and to be watchful against their recurrence. To this end, may we not get this habit: When we look at a lighted lamp let us consider the rays streaming from it as streams of coal made incandescent; and remember *So Long as the Light Flows, the Coal Flows!*

If it seems difficult to get every member of the family inculcated with the habit of light saving, then much may be accomplished by appointing one of the younger members a Light Monitor, charged with the duty of seeing that no extra or wasteful light is used. He will probably enjoy the duty and responsibility.

Recommendations for improving the efficiency of the lighting will be given in later paragraphs.

Having our equipment efficient, and desiring to further economize in the use of artificial light, *Let Us Not so Much Strive for a Less Lighted Room as for Less Rooms Lighted*. Can we not work toward the old idea of the Common Family Lamp, having it modernly equipped and supplying adequate light for all surrounding it?

RECOMMENDATIONS.

1. *Turn Off All Lamps Not in Use.*

Even if you are coming back in a few minutes, you can turn it on again. Pilot burners or wall switches will be found a great incentive to this practice where lamps are in intermittent use.

2. *Clean Lamps Regularly.* (Not Merely Occasionally.)

Dirty shades and reflectors may reduce your light one-half. It is proved economy to replace dim electric lamps or broken gas mantles with new ones.

3. *Keep Lamps Properly Shaded.*

Lamps having proper reflectors will give best service. Unshaded lamps cause eye-strain. Poorly designed shades waste light. Consult your lighting company.

4. *Use Only Modern Efficient Lamps.*

Replace open-flame burners with mantle lamps. Replace carbon electric with tungsten lamps.

5. *Regulate Light for Proper Requirement.*

Use turn-down lamps for hallways, kitchens, bathrooms, etc., where night lights are required.

6. *Avoid the Use of Lamps for Decorative Purposes Only.*

This is a form of extravagance unsuited to war times.

7. *Do Not Use Large Size Lamps in Small Size Reflectors.*

This results in exposed lamps and glare.

8. *Do Not Use Indirect or Semi-Indirect Units with Dark Ceilings.*

Such ceilings absorb too much light, instead of returning it downward in useful directions.

9. *Again—Do Not Use Artificial Light Where Natural Light May be Used.*

LIGHTING ECONOMIES IN OFFICES AND SCHOOL ROOMS.

Very large economies in the operation of lighting systems in offices and schools² may be effected by observing all of the precautions listed below, and this without reducing the general illumination, which is seldom of an intensity higher than that required for the conservation of vision.

Control of Lamps.—Operate the lighting units for a given area only when such area is in use. They should not be turned on during any part of the day when the natural lighting will suffice. Place the responsibility for such careful operation on designated individuals.

Parts of the room remote from the windows may require artificial lighting when natural light is sufficient near the windows. Connect the switches, if possible, so that the light sources may be turned on in rows parallel with the windows, and the artificial lighting thus used in the several sections only as is necessary.

Often the greatest waste occurs through the lighting of an unnecessarily large number of rooms during the hours of cleaning. Every building superintendent and janitor should insist that lamps be lighted in a given area only when the cleaners are actively engaged there, and that the minimum number be turned on which will permit the work to be done properly.

Cards or signs should be displayed prominently in the various rooms requesting tenants to turn on only such lamps as are necessary to their work and urging that all lamps be extinguished when daylight will suffice and when the tenant leaves his office.

² See "Code of Lighting School Buildings," Illuminating Engineering Society.

Reflecting and Diffusing Accessories.—Use bowl-frosted lamps with open reflectors and be sure that the reflectors are deep enough to protect the eye from the glare of the filament or mantle. Larger reflecting fixtures with glass diffusing bowls suspended below the lamps further soften the shadows and reduce the demand for local desk lighting. Indirect and semi-indirect fixtures produce the best conditions for vision in school rooms and offices.

Clusters of lamps under flat shades produce glare and distribute light ineffectively. The larger lamps are the more efficient. Therefore a lower wattage will suffice in a single large lamp with deeper reflecting or diffusing accessory.

Cleaning of Windows.—Windows should be cleaned at frequent intervals to allow the maximum use of daylight and limit the hours of artificial lighting.

Painting of Light Wells.—Paint the light wells white. This may reduce the period of artificial lighting by several hours each day, and improve the daylighting at all times.

Removal of Window Screens.—Where windows of offices are screened, the screens should be removed just as soon as the necessity for their use has passed. They absorb a high percentage of the daylight and require artificial lighting to be turned on for considerably longer periods.

Cleaning of Fixtures.—Dust accumulating on school and office fixtures frequently reduces the intensity by 25 to 50 per cent. Clean the units regularly and at short intervals to insure maximum output for the fuel consumed.

Wall and Ceiling Surfaces.—White ceilings and, to a lesser extent, light colored walls add greatly to the efficiency of any office or school lighting system. The added diffusion of light is also particularly valuable here. It is necessary that ceilings, especially, should be refinished whenever they become darkened. With indirect or semi-indirect lighting the refinishing of the ceiling and cleaning of the lighting units will frequently increase the intensity 50 to 100 per cent., permitting a reduction in wattage to the next lower size of lamp.

In offices and school rooms³ the requirements of vision are exacting. The occupants must view fine detail and work in one

³ See "Code of Lighting School Buildings," Illuminating Engineering Society.

position for long periods. The light from a lamp therefore enters the eye constantly from one direction and will prove annoying and harmful if too bright. Reflections from polished surfaces and sharp shadows also interfere with vision. If the general illumination is from amply diffused sources of proper wattage, all individual desk lamps may be dispensed with.

ECONOMIES IN FUEL FOR INDUSTRIAL LIGHTING.⁴

In almost every plant there is waste in the use of light, the elimination of which can be accomplished without retarding production, impairing the vision or menacing the safety of the employees. The principal sources of waste are the following:

Inefficient Lamps.—Replace carbon electric lamps by the modern efficient tungsten filament lamps. Substitute mantle burners for open-flame gas jets. These substitutions will result in a saving of three-fourths of the fuel used for a given candlepower.

Where clusters of lamps are employed under shades replace them by a single larger lamp with a suitable reflector. The larger electric lamps are the more efficient. A lower wattage may be used in a single unit than with a cluster.

Improper Reflecting or Diffusing Equipment.—Flat reflectors allow much of the light to escape to the walls instead of directing it to the work. They also leave the bright light source exposed to view and the glare interferes with vision, causing a demand for still higher intensities. Use reflectors of the dome or bowl shape for greatest economy. Except where lamps are mounted in high bay areas use bowl-frosted lamps to reduce glare reflected from the work and to soften shadows.

Faulty Location of Units.—Space lamps closely enough to give uniform lighting and with reference to the work, so as to avoid bad shadows. This permits the use of a minimum wattage in the general lighting and makes it possible to remove most drop lamps or local lighting. Drop lamps within control of the workman are frequently burned by him throughout the day when no necessity exists.

Maintenance.—Keep lamps and reflectors free from dust by a regular schedule of cleaning at short intervals. In many fac-

⁴ For information in regard to good factory lighting practice consult the "Code of Lighting, Factories, Mills and Other Work Places," Illuminating Engineering Society.

tories dirty reflectors absorb half of the light produced by the lamps.

Have windows washed frequently. This will greatly improve the natural lighting and permit the use of daylight alone for more hours per day.

Keep ceilings and upper walls well painted in white. When dark or dirty they will absorb so much light that more artificial light must be furnished.

Wasteful Burning of Lamps.—So far as possible do all lighting from a general overhead system out of the control of individual workmen. Make some individual in each department responsible for seeing to it that lamps are lighted only in such areas and for such periods as necessary.

Areas at a distance from windows often require artificial light when natural lighting is sufficient near the windows. Switching arrangements should be such as to make this possible.

TABLE I.

	Foot-candles* at the work	
	Ordinary practice	Minimum
(a) Roadways and yard thoroughfares.....	0.05- 0.25	0.02
(b) Storage spaces	0.50- 1.00	0.25
(c) Stairways, passageways, aisles	0.75- 2.00	0.25
(d) Rough manufacturing such as rough machining, rough assembling, rough bench work	2.00- 4.00	1.25
(e) Rough manufacturing involving closer discrimination of detail.....	3.00- 6.00	2.00
(f) Fine manufacturing such as fine lathe work, pattern and tool making, light colored textiles	4.00- 8.00	3.00
(g) Special cases of fine work, such as watch making, engraving, drafting, dark colored textiles	10.00-15.00	5.00
(h) Office work such as accounting, typewriting, etc.	4.00- 8.00	3.00

NOTE.—Measurements of illumination are to be made at the work with a properly standardized portable photometer.

* The foot-candle, the common unit of illumination, is the lighting effect produced upon an object by a standard candle at a distance of one foot; at two feet, the effect would be not one-half foot-candle, but one-fourth foot-candle, etc. A lamp which would give off 16 candlepower uniformly in all directions would produce a uniform illumination of one foot-candle at a distance of four feet in any direction.

The table of lighting intensities required in industrial processes (Table I) was issued by the Illuminating Engineering Society and subsequently adopted by the United States Bureau of Standards for the National Safety Code and government plants. The table has likewise been incorporated in the factory lighting codes or regulations issued by several of the state industrial commissions.

The desirable illumination to be provided and the minimum to be maintained are given in Table I.

DISCUSSION.

G. N. ALLEN, Acting Director of Conservation, U. S. Fuel Administration (Communicated): The different methods of conserving fuel through proper lighting as covered in detail in this paper are, and will be, of material assistance to the various departments here in the steps which they are taking, not only for better lighting, but also in conservation measures to assure proper economies in lighting.

One particular point in your paper which is of great importance is your comment as to the mistake which can so easily be made by failing to appreciate the impairment to health and service which might result in too energetic an effort to save fuel by decreased lighting, and such economies should not be proposed, except in cases of the greatest emergency. We feel that this point cannot be too thoroughly considered.

We know that a general understanding by the lighting public of the principles as involved in your paper, will not only mean proper economies for the wartime period which your paper is intended to cover, but many of the principles will be of great benefit if followed by the public after the war. We further appreciate that many of the principles as recommended are not what your Society would technically call proper lighting.

We thank you and your Committee for presenting this paper. We know the spirit in which it has been prepared, and we wish to ask you, your Committee on War Service and all the members of your Society, to accept the appreciation of the Administration for the service which it has rendered, which service we know they will continue to render in their respective vocations and districts. We know that without such assistance we cannot expect to get the necessary results in our efforts to conserve fuel. More

fuel means more steel and more steel means more shells, and the co-operation of the members of your Society in conservation measures assures us of a considerable fuel saving, which brings us nearer to the end of this war.

R. L. KESTER, Power and Light Section, U. S. Fuel Administration: I would like to state, yesterday afternoon before starting up here from Washington, Mr. Allen, who is the Acting Director of Conservation, requested Mr. Stuart and myself to be here and discuss in detail at such time as we can take up in this meeting, any necessary points relative to this program which has been submitted to us. Mr. Allen asked us to state to this meeting that it was not the intention of the Administration to enforce anything that seemed extremely drastic. He was under the impression that possibly some of the suggestions as made in this report, as submitted, might apply in some localities, and in other localities it would not, and for that reason we felt that before any formal programs were made out—were sent out by the Administration, that Mr. Stuart and myself should discuss these different matters with you gentlemen fully, so that we can act together. And in addition Mr. Allen wished to state that the Administration fully appreciates that the lighting industry in general is being called upon to probably carry a little more of the load than some other industries. He simply asked me to state that he fully appreciated this and realizing and wishing you to feel and to put yourself practically in the place of some of the men who are in the trenches, and in that way he wished me to try to convey to you and through you also to your respective districts that the Fuel Administration and the Government are trying to place you in that position in asking you for this co-operation. I don't think that there is anything further that I can state except to thank you gentlemen and your Committee for permitting us to be with you and to acknowledge the program which you have presented.

FRANK W. SMITH: There is, perhaps, no subject in which a large group of our membership is interested, that has been given more publicity than the subject of this paper or report of your Committee, namely, "Wartime Lighting Economies." I have

been asked by President Wells to present briefly the method employed by the National Electric Light Association in bringing the conservation program of the United States Fuel Administrator to the attention of our membership.

You are, of course, familiar with this program as applied to the manufacture, distribution, and use of incandescent electric lamps to conserve fuel. This program which was promulgated by the Fuel Administrator following a report made to and adopted by him through a special committee appointed for that purpose of which Mr. John W. Lieb is Chairman, has been given very wide publicity and has, unquestionably, been a factor in the saving of coal.

The details of the recommendation made have been brought to the public's attention, first by the Fuel Administrator in direct communication with all interests involved; second, through the instrumentality of the Lamp Committee of the Association of Edison Illuminating Companies; by the National Committee on Gas and Electric Service, and finally through the Lamp Committee of our organization, the National Electric Light Association.

Wide publicity has also been secured through the active operation of the daily and technical press. As I have said, all of the members of this Society are, no doubt, familiar with the detailed recommendations made by Mr. Lieb's Committee, adopted and promulgated by the Fuel Administration. Our Association was asked by the Administration to bring this program directly to the attention of our membership and to secure active co-operation in carrying out the recommendations contained therein insofar as they were applicable to Central Station companies.

The Lamp Committee, to whom the matter was referred by our Executive Committee, undertook to do this through the medium of its monthly *Bulletin*, which has a circulation of 12,000 copies or more among the membership, etc. This method was in itself, more or less, a conservation measure in that we employed the regular monthly organ of the Association rather than prepare a separate printed pamphlet involving extra expense, postage, etc.

In order, however, that the matter might come directly to the attention of Class A members, the Central Station companies, we addressed to this class of membership a letter which was brief and as follows:

TO MEMBER COMPANIES:

Your careful attention is directed to the current month's issue (Vol. 5, No. 8) of the Association *Bulletin* containing on page 470, in full, the fuel conservation program promulgated by the United States Fuel Administration, through the discontinuance of manufacture and renewal of certain types and sizes of inefficient incandescent lamps.

The Association has been asked by the United States Fuel Administrator to lend its aid in carrying out this program, and at a meeting of the Executive Committee held on Friday, the 13th instant, the Lamp Committee was authorized and directed to bring to the attention of the membership, through the medium of the monthly *Bulletin*, the details of this program.

Your Committee was also authorized to address a communication directly to member companies calling attention to the September issue of the *Bulletin* and asking for a hearty compliance with the provisions of the program therein set forth.

Please make a careful study of the recommendations made by the Fuel Administrator, and, so far as the same refers to Central Station companies, undertake to comply therewith in every respect possible.

It is urged that the widest publicity be given the matter either in the daily papers, house organs, or other advertising media, and through your sales organization to make the program thoroughly effective.

Your Committee would greatly appreciate it if you would advise what steps your company will take toward this end, putting us in possession of copies of all advertisements or other data that you may publish or issue on this subject.

Very truly yours,

FRANK W. SMITH,
Chairman.

The response to this letter has been immediate and most satisfactory. To date we have had more than 10 per cent. of replies and they are coming in daily. Without exception, the membership expresses itself in hearty accord with the program and offers to co-operate with the Fuel Administrator in every way possible towards its effectual adoption. Many examples are given in these letters as to the measures adopted. It is most gratifying to report a considerable number of companies formerly making free renewal of carbon and gem lamps, announcing their discontinuance of the use of these types of lamps. The method employed by the companies in the main has, of course, been publicity. The advertising columns of the newspapers have been largely used

and the ordinary method of utilizing house organs, circular letters, dodgers, etc., have been widely employed.

Time will not serve to review these methods, but one or two examples might be given. In sections where there is a distinct shortage of power, the methods of the Central Station companies have been more drastic, and most of you are familiar with these particular sections.

An advertisement was herewith exhibited of the Public Service Company of New Jersey which addressed itself to both the gas and electric consumers. The local companies here in New York have used the newspaper columns to considerable extent. An advertisement was shown of The York Edison Company, which was dignified and to the point. The Edison, United, and other companies here have circularized their customers directly as to the desirability of economy and use of higher efficiency lamps, etc. As most of you know, the local companies are now strictly on a merchandising basis so far as the incandescent lamp business is concerned and are not furnishing free renewals which was previously done.

I have in my hand an interesting advertisement of one of the Central Station companies—"Important Notice to all Users of Electric Service"—which gives notice that in compliance with the order of the Fuel Administration after October 15th, the renewal of incandescent lamps will be discontinued, etc. Some of the other ads. which are characteristic and of which we have many samples are also interesting. One company uses the slogan "Don't use the slacker carbon lamps."

A number of companies have utilized show window space to promote the use of higher efficiency lamps and to draw comparisons between these newer types and the old fashioned and wasteful carbon lamp.

Another advertisement headed "Carbon Lamps and War Regulations" directs itself particularly to the disadvantage of the use of low efficiency lamps.

In bringing this program of the Fuel Administrator to the attention of the gas and electric lighting companies, Mr. Lieb's committee, the National Committee on Gas and Electric Service, stated among other things that it was the intention of the Committee to prepare some suggestive material for advertising and

other purposes for use by the companies, and the speaker understands that the Society for Electrical Development has co-operated with Mr. Lieb's committee in the preparation of this material and that they have under way a series of advertisements, dodgers, etc., which Mr. Lieb's committee is to utilize.

I see that Mr. Wakeman of the Society for Electrical Development is here, and I hope he will have something to say as to the character of this material.

In conclusion, Mr. Chairman, I should like to urge that when this report of your committee is finally adopted by the Fuel Administration, it be given the same wide publicity that the report of Mr. Lieb's committee, to which I have referred, received. This report on "Wartime Lighting Economies" will tie in and will amplify the present program of the Fuel Administration covering, as it does, a wider field and range of fuel economy than the mere question of the use of incandescent lamps. It is very interesting in reading this report to note what simple, homely, and ordinary (if I might use these terms) methods can be used to accomplish real results in the economic use of fuel, and when one realizes that only $2\frac{1}{2}$ per cent. of the fuel consumption in the homes is devoted to lighting, we realize that the bigger economies can be accomplished in other directions than the mere question of lighting.

The great difficulty is, of course, how to accomplish these economies and how to bring home to the user the necessity of such economies and the ease with which the same may be accomplished. Of course if it were possible to bring home to every individual the necessity for doing the obvious and easy things such as cleaning windows, cleaning fixture glassware, using proper shades, and the many other directions pointed out here, great results could be accomplished and more fuel would be saved than through all the lightless night or signless night orders that have been issued. It must be borne in mind that these orders have been effective and have had good results. I would again suggest and emphasize that the report of your committee as finally adopted and approved by the Fuel Administrator be given the widest publicity. Of course it goes without saying that the National Electric Light Association will do its part in this work and that as an organization representing our membership we will

stand back of the Fuel Administration 100 per cent. in putting over their fuel economy programs.

J. M. WAKEMAN: I don't know how closely the illuminating engineers follow the commercial activities of the industry. But I presume you are all familiar with the work of the Society for Electrical Development, and probably all know of the Electrical Prosperity Week and other big sales campaigns which have been conducted by the Society; possibly it may interest you to know that since the Government has requested that no sales campaigns be conducted, the Society has diverted its activities into other channels, and is devoting most of its time and attention to moulding public opinion, educating the public to a greater appreciation of the services rendered by public utilities, and endeavoring to engender a spirit of co-operation between the public and the public utilities. The Society has placed at the disposal of the various governmental committees the large amount of data, statistics and information which it has collected in the last five years, and some of the Government committees have made use of it. Mr. Lieb, as Chairman of the National Committee on Gas and Electric Service, came to us, in view of our present activities, a week ago, and asked if we would prepare a series of advertisements to help along the campaign of more efficient and less wasteful lighting. I naturally told Mr. Lieb that we were ready to do anything we could to further the cause and I have had prepared by members of the staff of the Society for Electrical Development about twelve advertisements along those lines. I submitted those to Mr. Lieb on Monday of this week, and he has approved them. They are not yet in type, so that I could not bring them with me, and the necessary cuts have not been made because we have had difficulty in getting the artists who are now working on the drawings for them. But they will be made up into the form of a booklet nine by twelve, and distributed throughout the country for the use of Central Stations, jobbers, dealers, and others, as copy for their advertising. The advertisements are, of course, addressed to the public, and in them the public is asked to carry out the suggestions made in this paper by your Committee on War Service. As Mr. Smith was speaking and expressing the hope that this paper

would be given wide publicity, it occurred to me that we might possibly have the Illuminating Engineering Society print a sufficient number of these papers for us to include one with each of the booklets that we send out containing those advertisements, because the argument why those advertisements should be used, and suggestions for further advertising copy are right here in this paper, and I think if you would supply us with a sufficient number of them, we could include them with our booklet and send them throughout the country, which would insure a good wide publicity among all the lighting companies.

F. V. WESTERMAIER: At the request of the Fuel Administration, extended through the National Committee on Gas and Electric Service, the Committee on War Service of the Illuminating Engineering Society prepared this report, containing suggestions as guides for wartime lighting economies. If applied generally these suggestions will result in considerable fuel saving.

Considering the fact that only $2\frac{1}{2}$ per cent. of this year's total coal output of 700,000,000 tons, about 17,500,000 tons, are consumed in the production of artificial light, gas and electric, it is evident that even the most drastic economies in lighting could save only a small portion of the estimated necessary amount of coal needed for extra war requirements. Obviously, therefore, it is in the manifold uses of coal, other than artificial lighting, that much greater economies must be taught, and practiced, if the war ability of our nation is to be maintained.

Nevertheless, if any proportion of the coal used in the production of light can be saved through judicious economies by just so much is the production of coal assisted.

The suggestions made in this report are calculated to save fuel as a war measure, through the elimination of waste in artificial lighting. They are not to be confounded with the objects of this Society which are the preservation of the principles of illumination and their application as requirements for safety, conservation of vision, esthetics, comfort, convenience and efficiency.

The maximum use of daylight is urged. Cleanliness of windows and skylights, elevation of window shades, prompt removal of screens after the fly season, light colored ceilings and walls, whitened building exteriors, proper arrangement of working

planes with respect to windows, all tend to a more efficient, broader use of the natural illuminant, and a reduction of supplemental artificial illumination.

After the period of daylight, artificial lighting should be confined to the use of only necessary numbers and sizes of lamps. The use of the more efficient types of tungsten filament and incandescent gas mantle lamps is urged. Carbon filament and open flame gas lamps should be discarded; the economies in fuel consumption resulting from such changes are obvious. Also as in the efficient use of daylight, cleanliness of light transmitting and reflecting glassware means light and therefore fuel economy.

Properly designed and installed reflectors, also the white painting of wall and ceiling surfaces, all make for a reduction in lighting fuel consumption. A very proper warning is issued against the removal of reflectors and shades from lamps as a means of getting more light, but which really reduces visual acuity by glare effect.

Furthermore, as a strict war measure, the use of lamps for purely decorative effect is discouraged, although the retention of a reasonable amount of display lighting is appreciated as a means of maintaining the morale of the people.

The application of these general suggestions to store, hotel, home, office, school, and industrial lighting is shown.

In the section devoted to industrial lighting is inserted the table of lighting intensities required in industrial processes as issued by the Illuminating Engineering Society and adopted by the United States Bureau of Standards for the National Safety Code, and Government plants. This table is also incorporated in the factory lighting codes issued by several of the State Industrial Commissions. Safety and working efficiency require that no reduction in lighting values below those given can be made without serious impairment of necessary production.

After all, it lies with the individual to practice the economies which this report suggests, if the desired results in fuel saving are to be attained. Therefore, the information in regard thereto should be given wide publicity.

W. GREELEY HOYT: I have the honor to appear before this

convention by courtesy of Mr. George B. Cortelyou, President of the American Gas Association, as a delegate from that body.

Any movement toward economical lighting has the unqualified support of the gas industry; especially is this so in the present emergency. The American Gas Association stands squarely back of the Government to this end and will embrace every opportunity to evidence its purpose in this respect.

Quoting from the words of Mr. Cortelyou in his opening address at the first meeting of the American Gas Association:

"From the beginning of the world conflict the gas industry has put its forces and facilities at the call of the Government without selfish purpose or expectation of gain; it has rendered incalculable service, as official records at Washington will attest; it will continue to do so and will keep step with other legions of American business in the support of the Government at Washington and of our fighting men across the seas."

The gas industry is intensively engaged upon many wartime economies. In the lighting field might be mentioned, among other activities, the very wide publicity which is being spread throughout the country in advocacy of the use of gas through mantle burners displacing the "fish tail" or flat flame light so commonly used, which form of lighting is wasteful in the extreme and as such uneconomical.

The public is being urged to adopt mantle lighting not alone for the greater economy resulting, with increased illumination and low cost, but as a patriotic duty in that the use of gas, through mantle burners, will assist the Government in its endeavors to conserve fuel.

These remarks, in brief, will serve to indicate the attitude of the gas industry with respect to "wartime economies."

L. B. MARKS: The paper calls specific attention to the desirability of using daylight wherever possible, instead of artificial light. There is one thought that occurred to me that might be of value in this connection, and that is the dissemination of information to the stores along the various avenues that by removing obstructions from show-windows to permit daylight penetration, a great deal of artificial light might be saved. An investigation conducted in 526 stores in this city, located on Second Avenue from 116th to 126th Street, on Second Avenue from 85th

to 95th Street, and on Third Avenue from 117th to 127th Street, showed that the show-window obstruction varied from zero to 100 per cent., and that the average obstruction of all of the stores was 53 per cent. These results are assumed to represent an average condition on the avenues mentioned. This obstruction is due in a large measure to the goods that are exhibited in the windows, and also in a large measure to partitions and screens that are located behind the goods. It was found that in a number of instances it was possible to make a very radical improvement in the lighting of stores by removing some of the obstructions from the show-windows.

J. M. WAKEMAN: Mr. President, in regard to the subject to which Mr. Marks just referred, I would suggest that you bring that matter to the attention of an association known as the National Display Managers Association. The President of that association was on my own staff at one time, and I know that it was the idea of all the men at the head of that association, that all show windows should be enclosed, and they hammered that into all their members at their conventions and in all their literature and all suggestions which they sent out for display windows. They always advocated that the back of the window should be shut in so that the passer-by would not have his attention distracted from the contents of the window by being able to look through it into the store. Therefore if you want to get anything done in regard to changing this practice I think you should bring the matter to the attention of the Display Managers Association.

A. J. SWEET (Communicated): Curtailment of sign lighting, show window lighting and white way lighting is justified in part by the saving in coal thereby made possible, on the basis that any coal consumption, however small, which can be dispensed with without economic loss to society in general should be so dispensed with. The more important reason, however, for curtailment of advertising lighting is for the psychological effect upon the people. There are few measures which so effectively and so recurrently as the curtailment of advertising lighting remind the citizen that we are at war, that strict economy in every field and especially in coal consumption is the minimum duty of every citizen.

PROTECTIVE LIGHTING.*

The Plant Protection Section of Military Intelligence was organized when the Government entered into large contracts for supplies for military purposes. It became necessary for the Government to co-operate with owners of contracting plants in order to prevent interruption of production, by accidental fires, acts of incendiaries or the results of operating plants which were not properly guarded or lighted. This work also included the protection of plants against the activities of alien enemies either inside or outside the plant.

There are now 33 district offices of the Plant Protection Section located throughout the United States. Approximately 35,000 plants engaged in production of war materials are listed by the Plant Protection Section as requiring attention. Representatives of the Plant Protection Section visit and inspect these plants, suggesting improvements in protection where practicable.

The Plant Protection Section has on its staff men skilled in fire prevention and in police work. These men labor to avoid damage to plants due to accident or malice. They inspect buildings, walk the fence lines, question plant guards and later hold conferences with plant managers. In going from one plant to another they collect and transmit valuable information as to protective measures.

About a year ago Dr. Hollis Godfrey, Commissioner, Council of National Defense, arranged for co-operation of your Committee on War Service with the Plant Protection Section.

Among other things, this committee prepared a treatise on "Protective Lighting" which has since been published by the War Department. About 600 copies of this pamphlet have been issued by the Plant Protection Section. Numbers have gone out under other auspices. These pamphlets have suggested inquiries some of which are of a technical nature which I need not answer here. The time is auspicious for this Society to devise means for having its representatives in various cities to advise in matters of protective illumination.

Illumination is not understood. It is the exception to find an

* Abstract of addresses by Edmund Leigh, Chief of Plant Protection, U. S. Military Intelligence. Addresses made as follows: Pittsburgh Section, April 26, 1918; New York Section, May 9, 1918; New York Section, May 21, 1918; Annual Convention, October 10, 1918.

intelligently illuminated plant. It would be advisable for your Society to launch a campaign of education in this matter. Plant managers must be informed of the need for protection and the importance of physical defenses in safe-guarding their property. They must be brought to understand that good fencing is a permanent and valuable investment. The combination of a well-made unclimbable, and, above all things, a properly illuminated fence together with a well-lighted entrance and a good watch service afford effectual protection against damage from outside.

Plant managers are commencing to realize the value of such protection and are learning that the installation of good lighting and good fencing mean economy in watch service and a saving in insurance premiums.

My experience in police work has brought knowledge of the importance of darkness and light in the commission and prevention of crime. A few years ago a railroad suffered from larcenies in a certain yard. Patrols on regular beats failed to stop the larceny. We finally placed a lamp at the far end of the yard and located a watchman at the other end, and promptly discovered and apprehended the thieves.

Good lighting is not studied as carefully as it deserves to be by those interested in protecting property. By some of the old school it is looked upon more or less as an innovation along extreme lines—a fad—while there are others who use it in homeopathic doses without giving any careful study to the question of protective lighting as a whole.

There are certain standards to be observed in good lighting which, in their own way, are just as important as standards in other lines. One of the agents of Plant Protection recently reported that the lighting at a big Government plant was so poor that it blinded the sentries on duty, the shadows being so deep and the lights so intense that it would really have been better if there had been no lighting at all.

In the first place, each section of any given property has its own problems, whether it is in the outlying districts, in the immediate vicinity of buildings, or within the buildings themselves.

It is worthy of note that in employing protective lighting, the principle employed is to obtain strong contrasts between objects which it is desirable to see and their backgrounds. In camouflage,

for instance, the intent is to blend the background with the object. Light protection is just the reverse. In this regard, it is interesting to note that some backgrounds reflect much larger volumes of light than others: For instance, a brick wall gives off less reflected light than a wall painted green, while, of course, a white-washed surface helps to show up better than other surfaces. Now, in adapting lighting to such surfaces, we employ far less light where we have white surfaces to deal with than when we have dark red ones.

Generally speaking, it is the object of protective lighting to make all surfaces in the property reflect as much light as possible, so as to exhibit persons approaching them by contrast. Another principle of protective lighting is to so locate lights as not to blind the guarding force. These lights, if bright, should be screened in such a way that the eyes of the guards are not centered upon the source of light instead of upon the objects to be lighted.

To install a system of protective lighting in any property, a number of important facts must be ascertained in detail. One cannot simply glance over a blue-print and put in a lighting system. A minute and careful inspection is required, and this should cover night-time conditions. All reflective surfaces throughout the property must be considered and noted, these surfaces covering buildings as well as spaces between; also large piles of materials. Outlying and surrounding property and its relation to the property to be guarded must also be considered. Naturally, source of lighting supply, volume and intensity, must also be considered, together with distribution. Proper protection also involves whether or not there can be installed an auxiliary source of supply.

Weather conditions, especially fog, affect lighting, of course, and much depends upon climate. Suggestions have been made for penetrating fog with yellow light; but, so far, these experiments have not been successful, and, where fog is persistent, thick, and more or less permanent, the only safe reliance is additional guards to meet the unusual condition.

The main object is to eliminate dangerous shadows from the area comprised within the pale of the lighting system. I have often found what appeared to be excellent lighting conditions

defective because, here and there, in between important buildings, or running along the boundary lines of the property, there will be deep shadows in which persons plotting harm may lurk.

Safeguarding the system of lighting supply—so that it cannot be tampered with, or be injured by unauthorized persons—goes without saying. It is singular, however, that at times we find excellent lighting systems installed carelessly in this respect. Only the guards, or duly authorized persons, should be acquainted with switch locations for illuminating the property. This applies also to special units for particular areas.

We preach the value of permanent good fencing and permanent good lighting. We go farther, and where the plant has installed a searchlight we urge them to add another, making the one auxiliary to the other so that if one is out of commission, the other may be used, and both may be employed in times of fog or emergency. It is difficult for us to indicate any standard method of lighting. My advise to plant managers is to send for an illuminating engineer.

An illustration of our work in this connection is the case of an \$80,000,000 powder plant of recent construction. We arranged to have all wires buried. In addition to the ordinary lighting, on an adjacent hill there is a large searchlight which will command any part of the buildings and grounds. Every 300 yards there is a watch tower with a searchlight on top. These searchlights are for use only in emergency. Each tower has a telephone service, one connected with the other. The men in the towers have a view of the building interiors which are all well lighted, and the men in the buildings look across the yard to the lighted fence line and so get a silhouette of persons or objects in between. The most vital parts of the buildings are surrounded by three fences. In the nearby woods the underbrush has been cleared out and destroyed. The trunks and limbs of trees have been whitewashed. No one can walk among these trees or between the trees and the plant without being seen as a silhouette.

Plant managers are in a receptive mood for protective lighting right now. Illumination for protection, both exterior and interior, is ready for development by this Society. I say flatly that I know of nothing that is so potential for good defense as good illumination and at the same time so little understood.

Aside from the use of protective lighting for the purpose of augmenting safety from alien enemies, there is an entirely different aspect of the work which might be mentioned: this is the necessity for good lighting from a good housekeeping standpoint.

Good lighting has much to do with the showing up of sanitary and other conditions; it also affects the percentages of accidents, for, where there is poor lighting and there are deep shadows, there are sure to be a number of accidents. So, merely from welfare elements alone, we must see the necessity of good lighting.

DISCUSSION.

F. V. WESTERMAIER: My connection with the work of the Committee on War Service has been one of the most enjoyable experiences I think that I have ever had in semi-public work. It seems to me that one of the mistakes made in the efforts of the various administrations to encourage conservation has been in not giving sufficient publicity to the plausible reasons for the rulings made. I believe that as a class, or as a people, Americans are all amenable to reason. There have been so many excellent suggestions made in regard to the conservation of fuel, that if given the proper publicity, in which the psychological influence of light could figure profitably, they would be taken up by the people in the same spirit in which these measures are born. So it seems to me that the suggestions which have been made before this, in regard to publicity, should be given serious thought, and be put into practice. If we could get all the people to think about how light can be properly used and therefore how fuel can be saved, by cutting out extravagance, very material results would accrue, notwithstanding the almost impossible problem of trying to save so many million tons of coal per year on lighting. There is extravagance all around, and if we analyze that extravagance carefully, we will find that the best interests of the Society will be conserved through publicity in showing people especially during these times how to use this wonderful product of fuel efficiently and properly.

R. B. BURTON: Mr. Leigh's remarks on protective lighting were very interesting to me, in view of my having spent consid-

erable time on this kind of work recently. I notice Mr. Leigh did not make mention of the very comprehensive and intelligent bulletin recently published by the Adjutant General's Office of the War Department, on this very subject. This bulletin was compiled and edited by the members of this Society, specially appointed by the Government to report on better lighting methods for various war purposes. Those members interested in plant protection lighting who have not seen this bulletin, should obtain one for their information. I think it unfortunate, that this bulletin has not been more generally distributed, especially to the Works Managers of various plants turning out Government or essential war product.

During the last two weeks, I have been in consultation with the plant engineers of three large industrial corporations on the subject of plant protection night lighting. In each instance, this bulletin had not been seen or received by the superintendent, although these plants were engaged in war work exclusively. I think this bulletin with the instructions given therein should be given more publicity.

H. THURSTON OWENS: It has been stated that steel reflectors have been regarded by the Government as a non-essential. This means that the actual, and not the theoretical, saving in coal and the increase in production will actuate the War Industries Board in formulating a decision as to the curtailment in the steel reflector industry. Demonstrate that you can do something worth while, and the material will be available.

PRODUCTIVE INTENSITIES.*

BY WM. A. DURGIN.

From the tumult of conflicting and sometimes almost frenzied cries that food will win the war, or that ships, or Liberty Bonds, or the irresistible surge of the Yanks are the ultimate factors, it has gradually become clear that each of these is but a partial statement of the truth, that the war is to be won by essentials, and may yet be lost by non-essentials.

Coincident with this clearing of the fundamental question has been a stiffening of individual determination until every true American is fired by the burning desire to make himself essential. Many have been able to accept the simple and final solution of this desire by enlistment. Others, kept at home by non-combatant mouths which must be fed or by physical incapacities which cannot be ignored, are still held to the daily routine of business, and have used their best imagination to so apply their especial skill and knowledge as to make their little activities a vital factor in the complete and lasting defeat of the cruel madness of the Hun.

This spirit, the finding and perfecting of the essential application, has been marked among lighting men. The reports of the Society's contributions through its committees to particular lighting problems are, I believe, typical of the spirit of the industry. But only a comparatively small number of men can give valuable aid in such special research work, while several army divisions of those concerned in the production of lighting equipment, in the Central Station supply of energy, and in the effective application of light, have chafed and fretted for real opportunity. Looking to our several Government Bureaus for direction, we have indeed found some ways in which to help. The wise and complete program for elimination of waste in lighting has secured our whole-hearted support. The educational use of the reaction of lightless nights has stirred some satisfaction in its implied acknowledgment of the value of lighting in producing desired mental states.

* A paper presented at the twelfth annual convention of the Illuminating Engineering Society, New York, October 10, 1918.

But the war winning effect of all these measures after all seems a bit remote to the man filled with the fighting spirit. He wants direct action, he wants to apply light to war, and after careful survey of the field, he naturally turns to the production of war material as his real opportunity. How can light be used to make faster ships, more deadly shells, safer gas masks, sharper bayonets, and especially how can light help to produce these at once, while the spirit of victory is with us? Obviously this is no time for hair-splitting, but for prompt, definite, effective work. The question is not: What form of lighting installation will give the most perfect manufacturing results? That sort of problem has occupied our Society for some dozen years, and as I hope to convince you the result upon average practice has been hardly epochal. Our problem is rather: How can we alter existing equipment, quickly, at small expense, to secure a real economic war benefit to our country?

The beneficial effects of lighting in its industrial application have never been stated more clearly than in Professor Clewell's analysis published some six years ago. "Good lighting," he says, "increases production, improves accuracy, decreases accidents, removes eye-strain, makes general surroundings more cheerful, adds to the comfort of the workers, results in better order and improved neatness, and conduces to effective supervision." These claims every man believes who has had opportunity to observe the results of improved lighting. Indeed, there is now a semi-official backing, for if lightless nights have sobered us, surely improved lighting may be expected to spur us on. But improved lighting has been before the country for nearly ten years, and it would seem that is time enough to have secured realization of the truth if that truth has any large economic value, unless, perchance, it has not been properly presented.

In the crisis of war, from the viewpoint of the manufacturer, hard pressed to meet Government contracts, Professor Clewell's eight heads reduce to one: *Good lighting increases production.* For with omnipotent Government inspectors enforcing necessarily strict tests, improved accuracy means a greater proportion of output accepted. Decreased accidents mean less time lost, fewer men leaving for other work; decreased eye-strain, better product, longer production hours; cheerful surroundings and increased

comfort, retention of a full force of men; order and neatness, quicker and better execution; and more effective supervision, the elimination of mistakes, and especially of long unproductive conversations on the pleasurable expenditure of enormously increased pay.

For war, then, we claim that good lighting increases production and we have three questions before us:

1. Are the war plants well lighted now?
2. Is our claim of increased production really important?
—and if so,
3. How can we apply our knowledge quickly, cheaply, effectively?

In attempting to answer these questions in Chicago, we have considered ourselves most fortunate in having a fairly definite criterion for good lighting as established in the latest revision of the I. E. S. factory code. This, with the several published commentaries and the Wisconsin modifications, emphasizes principally a sufficient intensity of light in the working spaces and efficient accessories such as will reduce brightness contrasts to an acceptable degree. While the formulation of the latter requirement is still disappointing in its indefiniteness, it at least gives some basis for judgment, and a slight experience with existing plants shows it so far in advance of average practice as to be quite sufficient for our immediate need.

With three engineers carefully instructed in these intensity and brightness standards, we have undertaken an illumination survey of every industrial plant using Central Station service in Chicago which has a connected load of 100 kilowatts or more. At present, there are 663 such plants, of which we have surveyed 93. To be sure these are not all war industries, but a surprisingly large part are doing at least some war work, and there is no easy way of grouping the customers without a visit to the plant when it is almost as simple to continue the investigation and obtain complete data.

The 93 plants thus far surveyed total 17,400 employees, cover a floor area of 96 acres, and aggregate a lighting load of 1,420 kilowatts. While the survey is largely inspectional, listing the number, style and condition of units used, and applying arbitrary

utilization factors to obtain the intensities produced, very considerable confidence is felt in the average results which show a mean of $1\frac{1}{2}$ foot-candles now in use with variations from 0.01 to 10 foot-candles, and an average consumption of 0.33 watt per square foot and 80 watts per employee. For these same plants, the I. E. S. code would provide an average intensity of 5.5 foot-candles, 3.66 times the present level. The intensity would vary from 2 to 12 foot-candles; the average watts per square foot would be 1, and the watts per employee 240, or 3 times the present consumption.

This showing of the extreme inadequacy of intensity, judged even by the conservative I. E. S. standard, when our industries should be working at their maximum production or not at all, seems striking enough, but when the element of proper shading is considered, the opportunity of the lighting man becomes unquestionable.

The average of $1\frac{1}{2}$ foot-candles is produced principally by units shown in Fig. 1. These are not historical exhibits of the beginning of industrial lighting, but actual typical examples taken from large factory installations in exchange for new equipment last week. Similarly, Fig. 2 is not of Edison's early installations, but of conditions in two large plants just a few months ago. If our contention that good lighting increases production is true, here is a field second to none in its demand for Government enforcement of true conservation measures, but is our claim true? Again we have attempted to secure unbiased engineering data. As our engineers in making the lighting survey approach the plant superintendent without attempt to sell lighting or to introduce any commercial argument, but simply to secure the actual facts of his present installation, so we have endeavored to make unbiased engineering tests in representative plants to show the actual effect on production of increasing intensity and decreasing glare.

Such tests are much more difficult than at first thought appears. Our revised program contemplates a four months run, the first month with the equipment as it exists; the second with proper equipment to give 50 per cent. higher intensity than the maximum recommended by our code; the third month at the lower code level for ordinary practice or what is generally considered

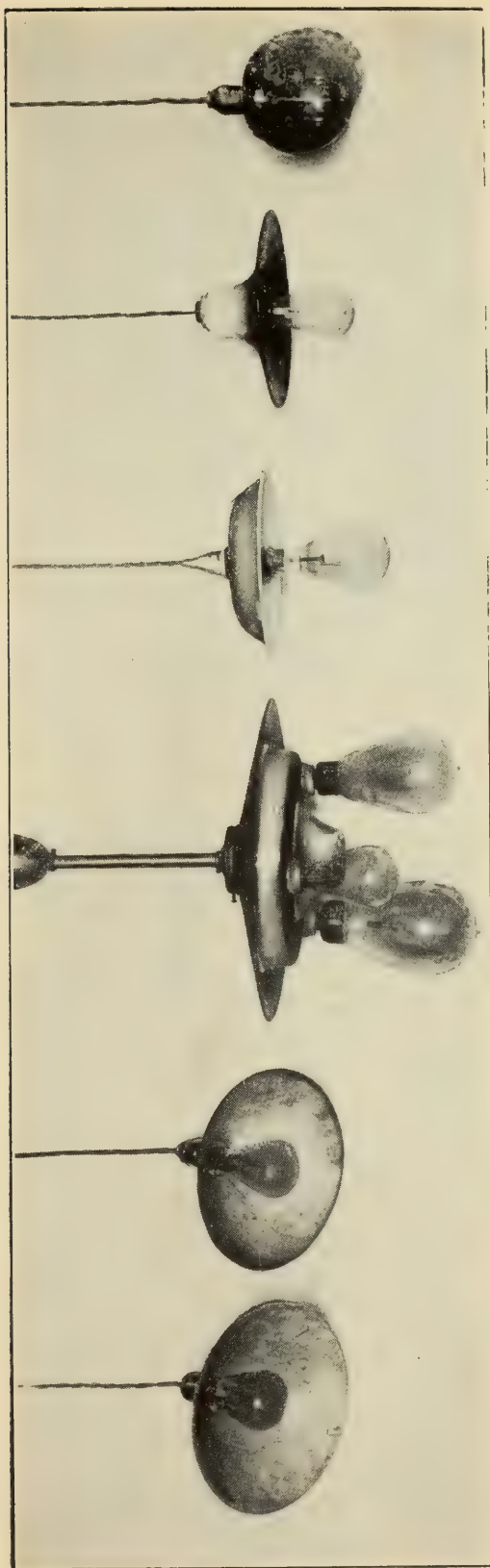


Fig. 1.—Typical lighting units now in use in the larger number of industrial installations.

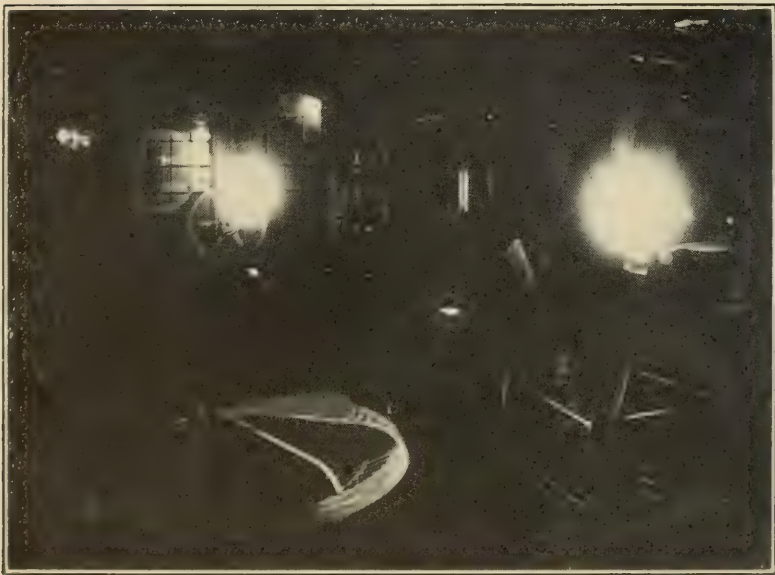
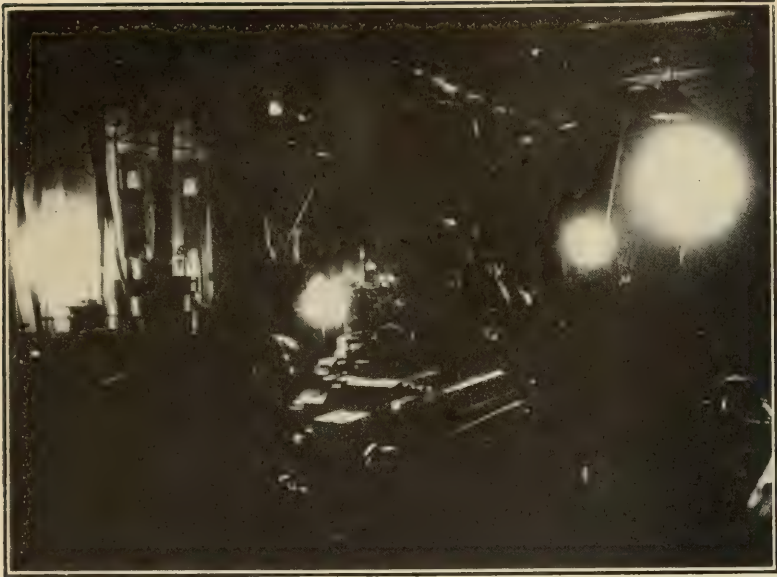


Fig. 2 —Lighting produced by such units as shown in Fig. 1.

good present practice; and the fourth again at the higher or productive intensity level. For such a test, the plant production records must be accurately kept and a fair percentage of the work must be done in hours of darkness. The chief difficulties are two: (1) To find plants with adequate production record systems, and (2) to induce the plant to return to the lower level of intensity at the end of the second month of the run after the advantage of good lighting has been once experienced.

Thus far we have sold the productive intensity idea and necessary equipment to eleven plants. From two of these we have secured reliable data. The first has already been noted briefly in Mr. Millar's paper on "Lighting Curtailment." The test was run in a machine shop producing soft metal bearings, operations ranging from rough to fine. Only two months of the program were run, but in the month at which the intensity was maintained at 12 foot-candles, production in the several operations was increased from 8 to 27 per cent. over that of the previous month when an intensity of 4 foot-candles was used. In this instance general lighting with deep bowl reflector equipment was employed for both intensities and every precaution taken to eliminate commercial bias. The superintendent was so impressed with the value of the higher intensity that he had it extended to the other floors of the building. In the second accurate test, the program could not be followed carefully, the comparison being between bare lamps on drop cords and a properly designed reflecto-cap installation. The new equipment gave about 25 times the intensity previously used, and showed an increased production of from 30 to 100 per cent. in the several operations of a large pulley machine shop. Again the superintendent was enthusiastic. In the other nine plants it has been impracticable to run tests, but in every case the superintendents and owners are fully convinced of the truth of our statement that the average effect will prove at least a 15 per cent. increase in production at an increased cost of not more than 5 per cent. of the pay-roll.

The investigation which perforce was allowed to lapse upon the entrance of our country into the war has been renewed with increased earnestness as it was realized that here lay the great opportunity for Central Station lighting business to serve.

We have three further test installations now under way, and

every plant surveyed is canvassed as a prospect for such test. We purpose to include at least 10 industries of as widely varying character as possible, bearing the expense of the trial equipment with the understanding that if the owner is convinced of its value, he will purchase after the test at our regular prices. But we feel that the data already at hand as supported by experience of lighting and industrial men in many cities is sufficient to warrant the acceptance of the proposition. There has been no slightest indication in the figures thus far that our claims are optimistic. On the contrary, it appears that the effect of sufficient light as a real productive element is a much greater economic advantage than we have appreciated. The need is pressing, and we cannot wait for complete proof; rather as in all war questions, we must accept that which is probably true, and pursue the chosen path vigorously and fearlessly.

For the period of the war good lighting in factories must become our principal objective, and to secure it we must be content with passable rather than perfect embodiment of the principles we have established. To get results quickly, it is impracticable to secure the absolute best equipment for each installation. In our own company, therefore, we have adopted definite specifications employing three general types of equipment:

- (1) Gas-filled lamps with steel reflectors and eye-shields in the 200-, 300- and 500-watt sizes.
- (2) Gas-filled lamps with deep bowl reflectors for extreme mounting heights.
- (3) Vacuum lamps and deep bowl reflectors for certain drop cord applications.

Our effort is concentrated upon the first class, examples of which are shown in Fig. 3. In using these eye-shield units, it is of first importance that the shields be sealed in place and only removable by the foreman or other authorized employee, for the ordinary workman believes but one part of the code. He wants more light, but he knows nothing of the effect of excessive brightness contrasts, and if left to himself will remove the shield as a useless obstruction. Recent installations of all three units are equipped with such sealing wires.

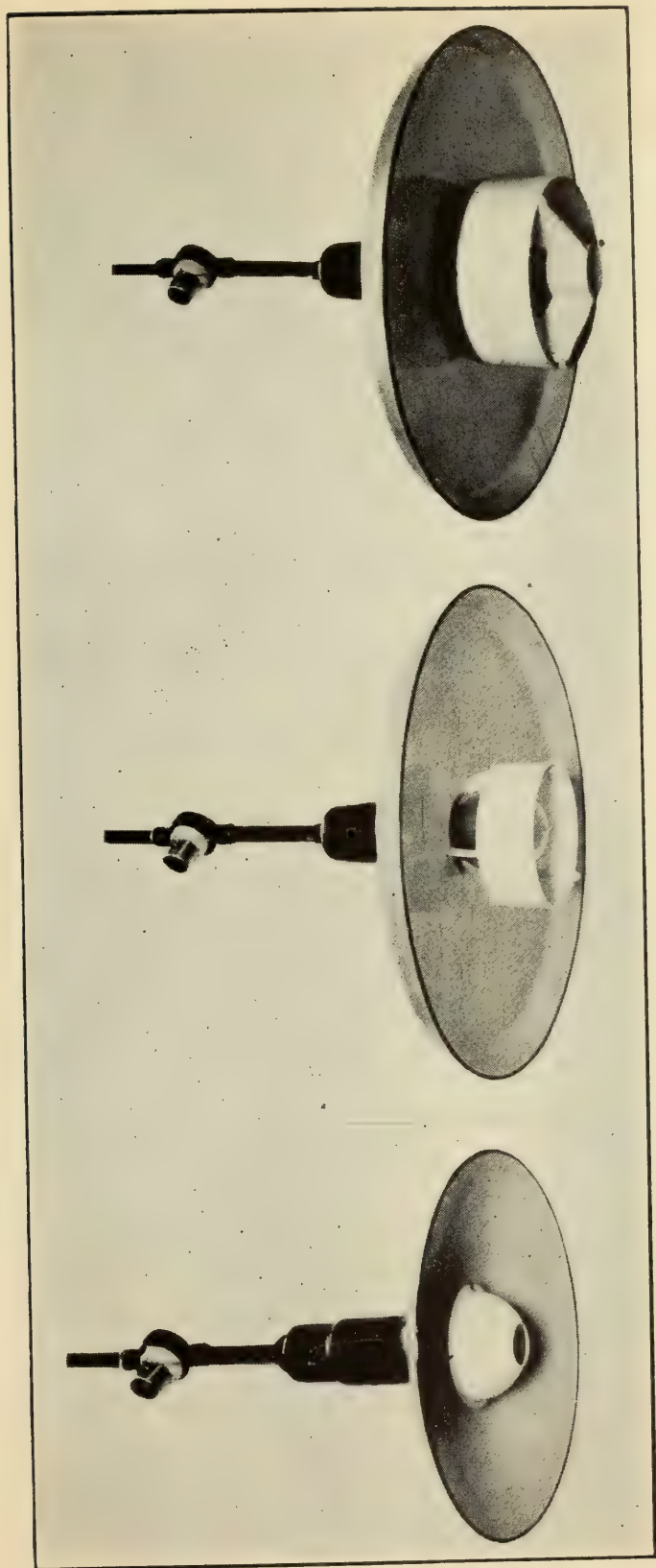


Fig. 3.—Eye shield for wide spacings giving productive intensities with 200-w, 300-w and 500-w "C" lamps respectively.

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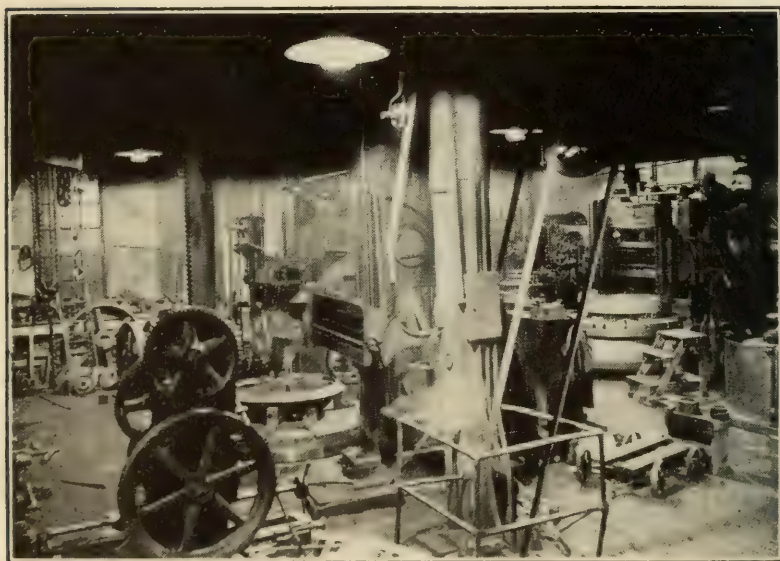
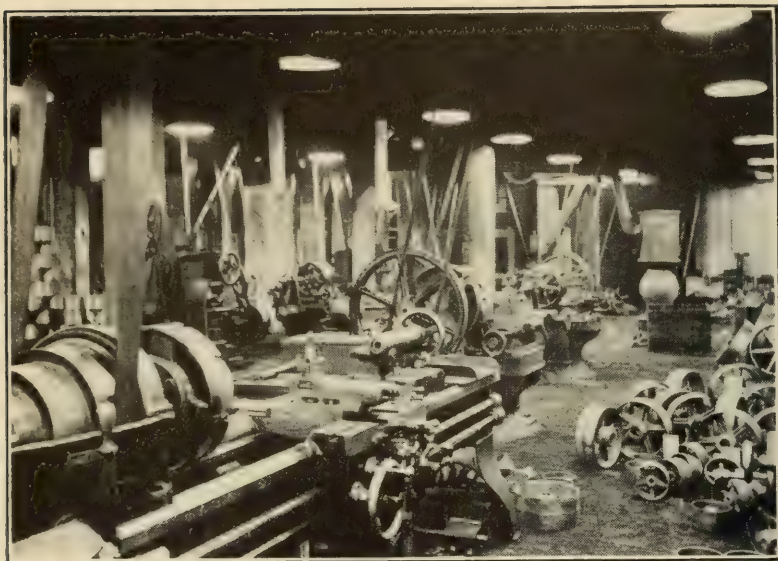


Fig. 4.—Productive intensity lighting in plants shown in Fig. 2. Upper figure using 200-watt reflecto-cap units, and lower figure using 300-watt eyeshield units.

Of the three we are especially emphasizing the 300-watt unit. It has an exceptionally high efficiency; a maximum brightness of 7,500 millilamberts on the interior of the diffuser ring, and is well adapted to installation on present outlets. This we feel is a particularly important consideration for the war drive. In many plants it is hardly possible to re-wire now; in others it is very questionable whether such re-wiring is warranted. But with this unit giving its maximum candlepower at the 50° angle, it is entirely practicable to produce reasonably uniform lighting with spacings of 14 to 16 ft. at mounting heights from 10 to 16 ft.

Where 12 to 18 ft. mounting heights above the floor are possible, spacings as high as 20 ft. can be used with 500-watt unit, with an acceptable result in uniformity of intensity and diffusion of light. This unit likewise, has a high efficiency and a maximum brightness of 2,300 millilamberts, view of the interior of the ring being largely cut off by the blades. The comparison between this approximation and the ideal is shown in Fig. 4. The 200-watt reflecto-cap units are on 10-ft. spacing—the 300-watt units on 16-ft. spacing at about the same mounting height with remarkable resultant uniformity. Again it may be emphasized that our object is not ideal illuminating engineering; it is practical application with as little change in wiring as possible to the end that transporting and protective fighting equipment may be produced with the speed which characterizes the advance of our victorious army. In these installations we are to secure productive intensity quickly at minimum expense with equipment which will continue to supply that intensity during its life.

Of primary importance, therefore, is the ease with which such equipment can be maintained. With the drop cord units of Fig. 1, bare or shaded by the tin dirt collector, even the extremely serious defects in intensity produced and brightness contrasts permitted are hardly as important as the extreme inefficiency which results after the machine has spattered them with oil, or the workman has manipulated them with dirty hands. We have tested several such units taken directly from factories, and have found the utilization efficiency less than 25 per cent. Now if coal saving through lighting is important, surely the maintained efficiency of large sources which can be reached only by regular maintenance men is worth our Government's consideration.

Maintenance of the lighting equipment in war work on a regular schedule should be made a part of the Government's mandatory supervision. It is best done by employees of the plant affected, but pending the Government's action, we are endeavoring to maintain factory installations in Chicago at cost, using our own men and visiting each plant at least monthly.

Surely the argument thus briefly summarized is valid from the manufacturer's viewpoint. With cold weather approaching and fuel none too plentiful there is, however, another viewpoint from which productive intensities must be considered. Admitting that output is increased at a negligible expense to the plant concerned, what is the effect on coal consumption? Productive intensity in general will mean three times the present consumption of electrical energy in industrial lighting. If output is increased 15 per cent., is that consumption warranted? For the 93 factories previously considered, the total consumption per month is 4,826,000 kilowatt-hours; of this 203,000 or 4 per cent. is used for lighting. To secure our productive intensity level would require a consumption of 640,000 kilowatt-hours, 13 per cent. of the present total or a 9 per cent. increase in fuel consumption. Fifteen per cent. output for 9 per cent. fuel is worth while in itself and will certainly appeal to the Fuel Administration. But when it is remembered that without that 15 per cent. output only 85 per cent. of the possible maximum fighting equipment will be in the hands of our boys for the final drive next spring, that without that 15 per cent. output perhaps 15 per cent. more lives of American youths must be sacrificed, the immediate realization of productive intensity throughout our industries becomes the essential service of the lighting men.

DISCUSSION.

PRESTON S. MILLAR (Communicated): One might epitomize Mr. Durgin's paper as follows:

A practical way for the civilian lighting engineer to contribute toward winning the war is for him to bring about the installation of good lighting systems of relatively high intensity in industrial plants engaged on war work. To do so is to increase production. A survey of 93 plants in Chicago shows an average of $1\frac{1}{2}$ foot-candles with an average consumption rate of $\frac{1}{3}$ watt per square foot

and with unscientific lighting equipment generally prevailing. The Illuminating Engineering Society's Code of Factory Lighting calls for good lighting equipment producing three times as much light. There is ample evidence to show that the provisions of this code are low and that for best economy and utmost production materially higher intensities are preferable. The best information available indicates that for the 93 factories investigated, trebling the lighting intensity and using scientific lighting equipment will increase the output by 15 per cent. with an increase of 9 per cent. in the fuel consumed by the plant. In this emergency 15 per cent. in output is worth more to the country than 9 per cent. in fuel.

This paper of Mr. Durgin emphasizes a fundamental which is very important to the industrial success of the country in war and in peace. It carries a truth which it is the patriotic duty of the Illuminating Engineering Society to drive home. Whether viewed with respect to its importance to the war ability of the nation or to the economic industrial success of the nation, or to the prevention of accidents, or to the conservation of vision, the conclusion is the same. Industrial lighting of high intensity which eliminates glare is important in the same way that good tools are important.

From the point of view of fuel conservation the paper has an application beyond that given by its author, and one which should not be overlooked in this connection. The necessary output must and will be obtained whether the lighting is good or bad. If produced under poor lighting at a production rate less than it need be, there will have to be 15 per cent. more plants or the plants will have to work 15 per cent. longer hours than would otherwise be the case. In that event the fuel consumed in order to obtain this 15 per cent. output will presumably be something like 15 per cent. greater. The choice is therefore offered of increasing production by 15 per cent. through good lighting at an expense of 9 per cent. fuel, or with poor lighting at an expense of about 15 per cent. fuel. With good lighting the production rate per ton of fuel is greater. In order to save fuel therefore industrial lighting should be good and of high intensity.

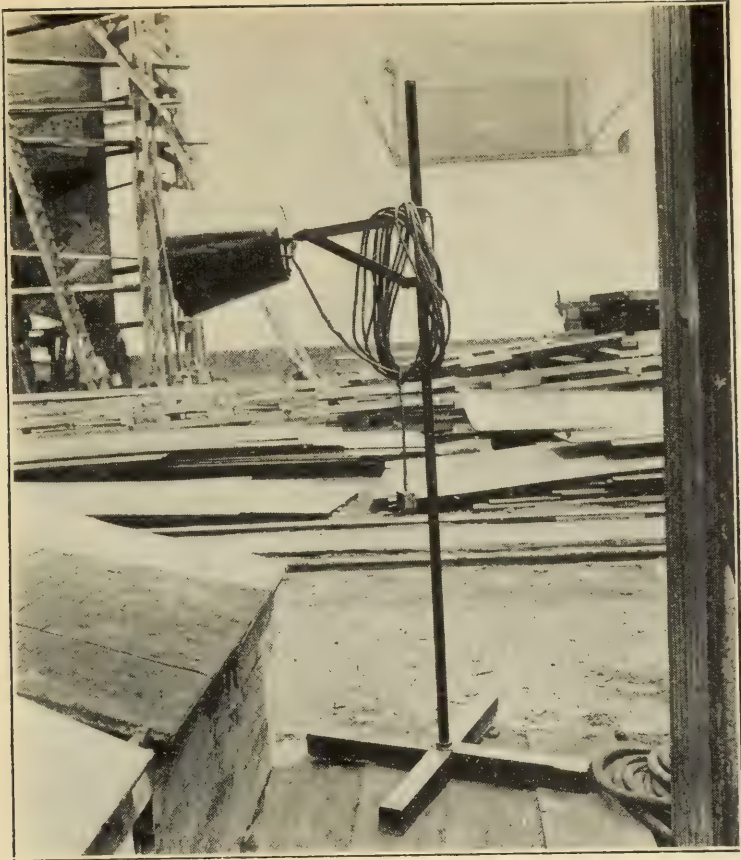
WARD HARRISON: As I listened to the last three papers I was much impressed with the accent that each one put on the importance of using good reflectors. At the same time I have heard it stated more than once during the last few months, that if the

production of metal reflectors were to be suspended during the war a very considerable economy in steel could be effected thereby. As a matter of fact, I believe that the total quantity involved is something like 2,000 tons of steel per year, and it occurred to me that you might be interested in knowing just what relation this bears to another possible economy. We have it on the best authority that the shortage of steel is due to the shortage of coal.

In the average modern factory interior a 200-watt lamp with metal reflector produces as high an illumination as a 300-watt bare lamp. Where ceilings and walls are dark, as in a steel mill, the additional wattage required in a bare lamp is much greater. For a plant operating twenty-four hours a day the difference of 100 watts per lamp means a saving of from 1,600 to 2,400 pounds of coal annually, which is sufficient to make 400 to 500 pounds of finished steel, or 150 times the steel required for making the reflector. If lamps were burned an average of only one-half the time required for all-night operation, 2,000 tons of steel made up into reflectors of this size would save 1,000,000 tons of coal annually, or enough to make from 200,000 to 250,000 tons of steel.

H. A. HORNOR (Communicated): The conditions in the various factories in Chicago so interestingly described by the author certainly point to the necessity for a more intensive propaganda for productive lighting on the part of our Society. He realizes as we all do that from our standard of lighting the workshops of our country were sorely in need of better illumination. Like many things which war has brought to the surface his paper indicates that there was no lack of enthusiasm on the part of the patrons whom he served in the realization of the output obtainable through the instrumentality of the illuminating engineer.

I do not consider that the membership of our Society can be charged with infidelity in the pursuit of the objects for good and effective factory lighting so well defined six years ago by Prof. Clewell. There are always two parties or more in the completion of a contract. Mr. Durgin in the latter part of this paper indicates the cause of the lack of completion of such a contract when he states the difficulties encountered in the factories experimented with due to the non-installation of production records.





This lack of account keeping for engineering purposes undoubtedly forms a large part of our economic waste. It should be emphasized that in our efforts to aid in better lighting we have laid our finger upon an equally important consideration. As in many other lines the managers of factories are willing enough in spirit, but lack the knowledge of the advantages to be gained in the application of better methods. The managements of companies of all kinds concentrate their minds upon the product which is the instrument by which they derive a revenue and a profit. On the other hand they little heed those who have carefully studied the subject which has nothing to do with the actual product of the factory and yet is a factor in increasing the output with a small expenditure in money and effort.

During the period of the war it has been my business to observe the entrance of a good many men into a field of industry which was very small at the opening of hostilities, but which has expanded many times within the last year and a half. I refer to the shipbuilding industry. Prior to the war I had suggested that the output of shipyards could be increased many times by operating both day and night. I was informed by the management of one yard that it was impossible due to the nature of the work to erect a steel ship by artificial light.

I was called upon as a consultant for a new yard. This same question arose. It was solved in a practical manner. The lighting units which were then available were not adaptable for the purpose. This made necessary the building of special outfits to secure the proper results. My friend Mr. I. S. Schlesinger had this work in charge and I present herewith several illustrations of portable fixtures which he has built. He is now using them for the purpose of overcoming the difficulties involved by the casting of heavy shadows by the scaffoldings surrounding the steel ship in the course of erection.

One of the difficulties in such an application is that the ship structure grows very rapidly under erection because of the large pieces which are handled at one lift. This makes necessary portable lighting units sturdy enough to endure rough usage and sufficiently light for rapid transfer.

In this particular field it has not been possible to collect data showing the increase of output. The reason for this is obvious

as all the efforts of the shipyard during the war have been concentrated upon the rapid construction of ships. It was not possible to undertake any special engineering experiments at this time.

Mr. Durgin's investigations in Chicago are deserving of a continuance in the approaching period of peace. It will be necessary now to vastly increase the output of our factories, many of which were non-essential plants during hostilities. Under the economic stress now before us every form of conservation must be as zealously enforced as during the war period.

The author is to be congratulated upon the clarity of his presentation and the interesting field in which he is pursuing his labors.

J. R. CRAVATH (Communicated): The experiments being carried on by Mr. Durgin and his associates are of the greatest practical importance. I am inclined to think, from the results already obtained by Mr. Durgin, and also from other confirming tests of a rather indefinite character, that too much weight has been given in the past to visual acuity tests, in which it is determined that after an illumination of $1\frac{1}{2}$ to 3 foot-candles is obtained there is very little gain in additional intensity. It is perfectly true that illumination of a character which produces glare from the work may be better if not carried to high intensities, but no such limitation exists on well-diffused illumination. For example, an illumination of 40 foot-candles by daylight from a North window is not complained of as being too intense. Again, the intensity of illumination is not necessarily a measure of the brightness, and it is brightness which counts with the eye. The fault has been with the interpretation of laboratory data rather than with the data.

The psychology of higher intensity lighting has been heretofore recognized only in a very indefinite way, probably because our data upon it has been very indefinite. It is beginning to be increasingly evident, however, from tests like those of Mr. Durgin's, that there is an element besides the mere ability to see clearly. There is undoubtedly a stimulating effect in higher intensity lighting. We know it to be true in nature with sunlight, and there is every reason to believe that the same principles hold in artificial lighting.

THE RELATION BETWEEN LIGHT CURTAILMENT
AND ACCIDENTS.*

BY R. E. SIMPSON.

One of the curious features of the war is the knowledge we have gained as to the comparative importance of various products or activities on winning the war. We have been told that coal, food, ships, aeroplanes, artillery—to mention only a few—will win the war. In fact, so many things have been mentioned that a visitor to this country facetiously remarked that naming them had assumed the proportions of a national pastime. Anyone may well hesitate therefore to add to the list of individual war winning essentials, but there can be no objection to directing attention to an item, the adequacy and proper control of which will have a vital bearing on the *duration* of the war, at least, and that is the ability of the home industries to provide the means whereby our army and navy may be made to function most effectively. Failure of our industrial man power and woman power to support our military and naval forces, results in a corresponding curtailment of the war ability of the nation. Anything that has a prejudicial effect on the output of our war industries must be subjected to a searching investigation, and the proper remedy, if such can be found, applied forthwith.

Even now there is an acute shortage of both skilled and unskilled labor, which is being made up, so far as possible, by the introduction of women into industries heretofore closed to them, and by drawing on men from non-essential occupations. This process must continue as fast as women can be trained, and as rapidly as we can determine just what industries are non-essential. The recently enacted law extending the ages for selective service will have the twofold effect of withdrawing more men from industrial pursuits, and at the same time of placing greater burdens on manufacturers of war materials. In order to alleviate the present labor shortage, and the threatened future decrease in the supply of workers, a nation-wide labor adjustment must take

* A paper presented at the twelfth annual convention of the Illuminating Engineering Society, New York, October 10, 1918.

place. In addition to this there must be a policy of conservation of labor, and the elimination of wastes and leaks, in the following out of which accident prevention will be an important factor.

The significance of the last statement will be readily appreciated if we consider the effect of accidents in terms of time lost. From the published statistics of a number of states, together with conservative estimates for the remainder, we find that approximately 25,000 persons are killed or permanently disabled, 500,000 seriously injured, and 1,000,000 slightly injured, each year. Translating these figures by means of the accident severity rates we have a total of 180,000,000 days of lost time. This is equivalent to the loss of the services of 600,000 men for a full year of 300 working days. This economic loss is distributed over the entire country during a period of one year, and for that reason its effects are not so keenly felt, or its importance recognized. If, however, this loss were concentrated on any one of our basic war industries, as for example, shipbuilding, steel making, munition manufacture, or coal mining, it would be nothing short of a national calamity. Even distributing this loss among the four industries named would seriously cripple all of them, and its effects would shortly be reflected by conditions at the battle fronts.

It is apparent that we have here an important factor touching on the supply of labor, and anything that can be done to curtail this economic loss is worthy of careful consideration. There is a certain percentage of unavoidable accidents—that is, man's prevision is unable to cope with unknown factors, and this is especially true of pioneer work. The best that can be done is to profit by experience, and endeavor to prevent the knowledge and experience thus gained from lagging behind practice. A large percentage of accidents may be classed as avoidable in the sense that the application of mechanical safeguards and the observance of safety rules will prevent them. Anything in the form of a practicable guard, of safety education, or of safety regulations that will protect the worker from injury should be welcomed by the plant manager to-day. Past investigations have indicated various influences on the causation of accidents, and prominent among these is industrial lighting.

A survey of 91,000 accidents from the records of The Travelers Insurance Company for the year 1910 showed that 23.8 per cent. were due to improper or inadequate illumination. Bearing in mind the progress in the art of illumination during the past eight years, it is hardly possible that this percentage prevails to-day. New factories are lighted by up-to-date equipment, while many old plants have had their lighting systems brought into conformity with modern practice. These are steps in the right direction, and are bound to be reflected in the accident rate. Offsetting this, to a certain extent, is the practice of many plant managers of substituting high efficiency lamps, both gas and electric, for low efficiency lamps, without providing adequate reflector protection. Notwithstanding the vast amount of expert advice that has appeared in the technical journals devoted to specific industries, there are literally thousands of plants that have not profited by this advice. The directing personnel of these plants, from managers to sub-foremen, do not seem to appreciate the difference between light and illumination, between a reflector and a wire guard.

There is some foundation, however, for assuming that 18 per cent. of our industrial accidents are due to defects in the lighting installation. On that basis the services of 108,000 men for one year are lost annually, because the illumination provided is not adequate for the safety of the workers. That this condition should exist year after year is all the more reprehensible because of the fact that the remedy is so easily applied and has beneficial results in many ways other than in the element of safety involved. Accidents caused by carelessness, inattention, or ignorance can be eliminated only by a long continued, painstaking educational campaign often involving a change in long established habits. The elimination of accidents due to inadequate or improper lighting is simply a matter of purchasing approved equipment and installing it under competent direction. In fact, it seems proper to include illumination in the list of mechanical safeguards, for the reason that the lamps and reflectors provide the guard—illumination—to point out the hazard, just as effectively as a railing points out the danger of and provides protection against the hazard of a revolving flywheel. The sum involved is insignificant when compared with the accident claims, or the lost

profit on the product of the labor, or the value of the product itself.

Anyone who makes an extended survey of the lighting conditions of our industries will inevitably be impressed by the much larger percentage of *improper* installations when compared with the *inadequate* installations. This is due primarily to the praiseworthy, but none-the-less ill-advised, attempts to better the plant illumination on the basis solely of providing a greater candlepower output. The questions of distribution, diffusion, and absence of glare are either not fully appreciated, or are entirely unknown, and therefore do not receive proper consideration. Now if the persistent efforts of several years have not wholly succeeded in educating the factory managements in the fundamentals of good illumination, is it not absurd to expect intelligent application of hurriedly promulgated rules for light curtailment? This in itself should be a sufficient argument against any such action, and it is rather gratifying to learn that there will be no general request for diminishing industrial lighting.

The saving in coal by curtailment of industrial lighting would be negligible when compared with the ultimate economic loss. If, for example, the full year's labor of the 108,000 men that is lost annually, due to poor illumination, could be saved and applied to coal mining, 130,000,000 more tons of coal could be produced. To provide ample illumination for the safety of all these workers, ten hours a day for a full year, would require less than 10,000 tons of coal. We may convert this fact into a more detailed and concrete form by saying that a 25-watt lamp burning ten hours a day will provide adequate illumination on a stairway for one year by the use of one-eighth of a ton of coal. By dispensing with the lamp one-eighth of a ton of coal will be saved, but if during the year one accident occurs involving the loss of only one day's time the economic loss from a coal producing standpoint would be sufficient to operate the lamp 32 years.

This brings us up to the point of considering the effect of diminished lighting at places where such reduction is almost invariably found. Stairways, elevated gangways, passageways, and storage spaces are generally inadequately lighted, and are the first to suffer from a policy of light curtailment. The hazards associated with these poorly lighted sections of our industrial

plants have been portrayed many times. Confirmation of these hazards has been given by the report of the British Government survey of industrial accidents showing that 40 per cent. more men are injured from falling and stumbling in the winter months than in the summer months. This is exclusive of street slipping accidents. The physical condition of the stairways and passageways is the same for both periods, the sole difference being in the illumination.

Many accidents occur in storage places due to inadequate illumination, but this fact is not often brought out in the reports. Raw material and finished product are often piled in uneven tiers, and these fall over at inopportune moments. Carelessness is very often the contributing cause, but in many cases a conscientious worker will pile material unevenly simply because the illumination is not sufficient to show him that the tier is out of alignment. Similarly, in storing tools or small parts on shelves some are placed too near the edge and fall on workmen. A case in point is that of a young man who was storing small diameter steel rods. Unnoticed by him, one of the rods protruded a foot or more beyond the edge of the shelf, and in passing this point later on he received a jagged cut along the side of his head. There was a small-sized drop lamp in the central aisle, but none in the side aisle where the accident occurred.

Even the supposedly well lighted working spaces in some shops are not immune from accidents of this nature. A certain work bench was well illuminated by local lights with proper reflectors, but the bench cast a shadow on the floor while the general illumination was not sufficient to offset the shadow. There followed a sequence of accidents due to the toppling over of partly finished work piled in the shadow. With a higher intensity of general illumination, accidents of this type were largely eliminated. Passageways that are traversed infrequently hardly justify the continual use of an illuminant, unless there is exposure to moving machinery or other hazards. Irrespective of the danger element, all passageways should have lighting units so installed that they can be turned on and off at either end. The lack of such a provision was partly the cause of an accident to a carpenter who had been called in to make some repairs in a chemical establishment. A cup had been placed to catch the drip from a

slight nitric acid leak until repairs could be effected. The carpenter, assuming that the cup was placed to catch oil drip, poured some of the acid on his saw and then rubbed it with his hand. Before neutralizing agents could be applied the palm of his hand was badly burned. It is evident that if proper illumination had been provided the carpenter would have noted that neither the color nor the consistency of the acid corresponded to that of an oil that might appropriately be applied to a saw.

A method is open to plant managers by which, at the same time, coal will be saved, better illumination provided, and accident hazards reduced. It consists in the universal use of reflectors. Every plant manager (as part of his lighting policy) should adopt the principle of a proper reflector for every lamp. In the field of general illumination, the use of unshaded lamps, in connection with naturally dark walls and ceilings, or with white walls and ceilings that have become dirty, is not only wasteful and inefficient, but also increases the accident hazard from bright light sources. Proper reflectors would bring this wasted light under control, and at the same time reduce the accident hazard. In a limited number of cases smaller lamps could be substituted and still ample illumination would be provided; but for the most part reflectors should be used with the lamps now installed to bring about a much needed improvement.

In the field of local lighting there is much more room for saving and improvement. There are thousands of 120-watt carbon lamps, and many more thousands of 60-watt carbon lamps, used for local lighting about machines. It is the exception rather than the rule to find these lamps equipped with reflectors. Wire guards are more popular. For purposes of illumination a 15-watt or 25-watt tungsten-filament lamp with proper reflector would prove adequate. The question of serviceableness or of breakage of this lamp over the carbon lamp is dependent on local conditions. The recent agreement between lamp manufacturers and the Fuel Administration insures a reduction in the use of carbon lamps. In enforcing this policy, lamp users should be warned against employing tungsten-filament lamps without reflectors. Exposure to the high intrinsic brilliancy of the tungsten filament involves a greater degree of vision impairment than with

the carbon lamp. Wire guards will not serve, for although they protect the lamp from breakage to a certain extent, they afford no protection to the eye. The lamp can be replaced for twenty-five cents, but the eye—vision—ininitely more valuable, cannot be replaced at any price.

During a recent inspection we noticed a workman at a stamping press who persistently stood at one side of his machine. In answer to our inquiries the workman stated that he could not see unless he moved to the side and closer to the lamp; and he also informed us that he was going to get a "big tungsten lamp." He was working on large tinned sheets, and while standing in front of his machine a dazzling reflection was directed toward his eyes. A simple adjustment of his local light changed the angle of incident and reflected rays, and thus removed the trouble.

This incident is more or less typical. There is so much unintelligent use of light in the form of unshaded or improperly placed lamps that we are fast approaching the state of being a nation of eye-glass wearers. An important remedial step will be taken when we whole-heartedly get behind the movement of "a proper reflector for every lamp."

DISCUSSION.

CHESTER C. RAUSCH, Assistant Director, The American Museum of Safety (Communicated): There are two outstanding features concerned with the use of electric lights in illumination for the factory or other purposes. First, the almost universal tendency of those concerned in the maintenance of such equipment to allow it to become filthy with an accumulation of dust or smoke, particularly the reflectors; then when this condition has become intolerable, to attempt to relieve it by the addition of high candlepower lights or the removal of reflectors, or both. The eye-strain resulting from the exposure on any portion of the eye retina of the light from a modern high power nitrogen light is sufficient, in many instances, to cause momentary blindness when the eye is turned away from that source of light. Where such lamps are used in the vicinity of the point of operation

of any machine, there exists the almost certain possibility that eventually an accident on that machine or device will result. The use of proper reflectors in such cases should be mandatory.

The loss of illumination due to the coating of reflectors with dirt may result in a loss of light equal to 60 per cent. or more, before attention is given to the fact that they need cleaning. The results where systematic cleaning of all reflectors and equipment has been followed, show a reduction in current consumption that, in many cases, has not only eliminated the need for additional installation of lamps, but has even reduced the necessity for using those already installed.

Many owners concerned with the maintenance of illuminating equipment complain that the cost of systematic cleaning is great, but such an argument can scarcely stand against the evidence repeatedly shown that accidents occur where illumination is poor on any one of the several points of quantity, intensity and diffusion. The proper installation of lighting equipment with reference to galleries, windows or other means of reaching the lamps, when fixed, or by the replacement of fixed lamps with those which may be lowered readily, disposes of this objection. That there is a direct relation between poor illumination and accidents is shown by a comparison of the number of accidents that occur during the course of the year when artificial light is used to supplement natural light in a portion of the working period, and where natural light is sufficient for all illuminating purposes. A "Study of Accidents for the Year 1917" of the Portland Cement Association, shows the percentage of total accidents for twenty-four hours, ranging from as low as 7.3 per cent., between 12 and 1 P. M., to as high as 13 per cent., between 5 and 6 P. M., or almost double. A similar frequency is also noted between the winter months; and the two, those for the hours of the day and for the months of the year, coincide almost exactly.

It takes only a casual observer without any technical training whatever to observe the enormous difference in the illuminating effect obtained in shops where the walls are kept smooth and clean and of light color, as against those where the opposite conditions prevail. One has but to recall his own experience in two rooms in his own home, in one of which everything is of light color, and in another of dark color; or of conditions that prevail

when snow is on the ground, and when the ground is bare and bleak, to remember that even when it is supposed to be dark, the ability to get about is greater under the lighter conditions than under the dark.

When manufacturers and others whose places of employment or work require illumination learn that less light properly distributed through fixtures properly maintained costs less for current consumption, a long step will have been taken in the matter of illumination; but when, coupled to this, they can be convinced that the number of accidents is proportionately less, we will approach more nearly desirable illumination.

A. J. SWEET (Communicated): Probably less than 5 per cent. of our industries represent in their lighting practice a close approximation to the best practice attainable in the present state of our knowledge. An additional 25 to 45 per cent. of our industries have made a good beginning toward providing adequate lighting, though their practice falls far short of the attainable ideal. The remaining one-half to two-thirds of our industries are characterized by grossly inadequate lighting.

It may be conservatively estimated that, in this year A. D. 1918, the application throughout American industry of our best present knowledge in the lighting field would result in a 15 per cent. increase in industrial production.

Consider what such an increase means. It is equivalent to the production of an army of approximately one and one-half million workers; an army that consumes neither food nor clothing nor wealth in any form; an army that produces without additional factory buildings or machinery or tools; an army that gives at least two-thirds its wages to be divided between capital and labor.

Moreover, such improved lighting means a material decrease in spoilage resulting from imperfections in workmanship. Such spoilage varies so enormously as between different industries and between different industrial operations that it is impossible to estimate its total in American industry with any degree of accuracy. It is safe to say that the decreased spoilage made possible by adequate lighting throughout American industry represents an annual net value of not less than \$100,000,000. In terms of labor, this represents an army of not less than 100,000 men.

It should be emphatically pointed out that such "best lighting practice" involves a great deal more than the sufficient and proper quantity of light. It involves light of the proper quality, particularly with respect to diffusion. It especially involves the highly important consideration of the direction of the light rays with respect to the plane of the work. Sometimes the elimination of sharp shadows, sometimes the avoidance of such elimination, exercises an important influence upon the efficiency of industrial work. The proper screening of the light sources, to the end of attaining conditions under which eye fatigue is reduced to a minimum, is still another factor of large importance.

In short, the attainment of "best lighting practice" is a complex technical problem requiring for its fully adequate solution the services of the competent lighting specialist. The failure to recognize this is one of the factors retarding proper practice in the industrial lighting field. It is very difficult to convince the average industrial manager that he is not fully competent to decide his own best lighting practice, to solve his own lighting problems.

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No. 9

THE ILLUMINATING ENGINEER AT WAR.* PRESIDENTIAL ADDRESS.

BY GEORGE H. STICKNEY.

In presenting the constitutionally required address, it seems best to depart this year from the usual practice and instead of discussing a scientific or technical subject, to direct your attention to the work of the Society and illuminating engineers in general, as related to the nation's needs.

War is the one theme which is uppermost in our minds at the present time. Our most important problems are concerned with winning the war—completely and promptly.

While it has been repeatedly emphasized by deed and by word, our American people do not yet realize the seriousness of the threat, which the most dastardly and atrocious foe of the ages has put upon us. On account of our remoteness and our altruism, we have not appreciated the extent of the possibility that some devilishly ingenious development might bring atrocities to our own homes. Fortunately, we are absolutely committed to the defense of democracy. We cannot consider anything short of complete victory, lest our sacrifices be in vain, and our future unsecured. Anything which speeds that victory means saving lives. Anything which we do or do not do, which delays the victory, even a few minutes means so many more of our men sacrificed, so many more homes saddened with the shadow of premature death.

In the face of this, our ordinary interests of comfort, convenience, or profit sink into insignificance. And especially should

* An address presented before the 12th Annual Convention of the Illuminating Engineering Society, New York, N. Y., October 10, 1918.

such interests yield cheerfully, since even they are not secure until the menace is removed. In line with this idea there has been but one fundamental thought back of the activities of the Society, since our country became a combatant. How can we best help win the war?

For about 12 years, the Society served the country and mankind in general, by building up the lighting art into a serviceable structure of standardization and practice. When the Society was organized, good lighting had been done, but any real knowledge of the principles was in the minds of but very few. There was no systematic interchange of experience; every expert kept his information, as far as possible, to himself, as a trade secret.

The Society has been influential in the reversal of this policy, and has become a power for encouraging the extension of the knowledge of lighting. Through this factor alone, it is largely responsible for the wonderful advance in lighting practice which the past decade has witnessed.

When the Society entered the field, it found the engineering features of lighting the most neglected, and naturally, its effort was concentrated, in a considerable degree, on the development of that phase of the art. In later years it has broadened its scope and given ever increasing attention to those features which made for beauty, comfort and convenience. It was not content to limit its work to the determination of scientific fundamentals, to enhancing safety and conservation of eyesight, to analyzing economic factors, but without neglecting these things began to build for better artistic lighting with the view of making people happier. The Society can well be proud of this structure of practice as a great national service.

But in wartimes, many of the aspirations of peace must be temporarily abandoned. No art can have first claim so long as there is the slightest possibility of our free institutions being menaced. And so we have been glad, not only to put our art at the service of our country—but have willingly sacrificed our aims and aspirations to any necessary or desirable extent.

It has been the chief aim of your officers to put the Society and its membership most effectively in the service of the country. This has not always been an easy matter. The difficulties have not come from any lack of support on the part of the member-

ship, but rather from the very rapid reorganization of the country on a war basis. The problem has been to determine how, or through what channels, our abilities could be most effectively applied. The splendid individual initiative of the American people has sometimes been an embarrassment. Organized effort is needed, and we must work in co-ordination with organized agencies of the Government.

In the first confusion, it was often difficult to determine with which of several agencies, more or less official, we could render the most effective service. In this connection, it must be remembered that excellent and well intended individual effort may actually be harmful, if not properly co-ordinated with authorized agencies. It has always been the aim of the Society to work harmoniously and never competitively with such agencies.

The National Committee on Gas and Electric Service has been the means of opening to us many opportunities for service. We have been fortunate in establishing representative relations with the War Committee of Technical Societies and with the National Research Council.

The Divisional Lighting Committee, under the Council of National Defense, is composed of active members of this Society and co-operates with our Committee on Lighting Legislation. On nomination of the President of our Society, a representative of the Divisional Lighting Committee for each state is being appointed to extend the adoption of industrial lighting codes.

We have found that those in authority, lacking our familiarity with lighting applications, do not always realize the great advantages latent in the new art of controlled lighting. It is, therefore, a difficult though pleasant duty to endeavor to convince them of its importance.

In the trenches or on the sea, light can be used to reveal the enemy, and often to confuse him, and an advantage in these respects may turn the tide of battle. Further, light is an important means of signalling both by day and by night.

In caring for and supplying an army, effectiveness depends, in a large degree, upon light. If the movements near the front could be illuminated for the benefit of the traffic, without revealing it to the enemy, there would be a remarkable gain.

In transportation on land and sea, and in production at the

workshop and mine, properly applied light is an essential factor. We may never know how momentous a part is being played by the teachings of our Society applied by our members and others. The importance of this feature was forcibly drawn to my attention last October, when assistance was sought by a leading member of the Naval Consulting Board on an important marine problem, involving daylight conditions. Practically all of the useful published data which we could locate were those in the TRANSACTIONS of the Illuminating Engineering Society.

In studying these various war lighting problems, both for the Society and in my professional capacity, they seem to divide themselves, so far as practical method of treatment is concerned, into two groups, namely, confidential and public. Many of the most important problems, especially where scientific development is concerned, fall in the former class. To discuss them publicly would give comfort to the enemy, with the probability that

1. The application would be rendered less effective through its existence being known;
2. Or a supplemental development might be made to take advantage of the application;
3. Or the application might be duplicated.

While much of the most interesting development falls in this class, we must continue to shroud it with secrecy and render our service confidentially, as individuals or as small committees discreetly selected. The enemy will learn of new and important light applications soon enough. But let us hope that the knowledge will go in the way which means maximum discomfort and least advantage to him.

Less spectacular, often less interesting, but nevertheless highly important, are those problems of general lighting practice, which are dependent upon the co-operation of the lighting industries and public generally for their success. Such problems must receive as much publicity as possible as soon as definite plans or programs are formulated. These problems include those phases of lighting practice which relate to efficiency of industry, to protection of lives and property, and to conservation of fuel.

Our Committees have rendered important service in connec-

tion with such activities, and one of the main purposes of the present meeting is to inform you regarding these matters, secure your advice and discussion, and to urge you to such action as will help assure and hasten the winning of the war.

It is not necessary for me to go into detail in regard to these matters, because they will be ably presented in the reports and papers, but it seems worth while to discuss them somewhat in general.

In order that our soldiers may continue to hurl shot and shell at the enemy, there are many activities which must be carried on in this country; ships and munitions must be made, materials must be produced and transported, and all these things must be done promptly. It is also necessary to care for the essential welfare of our entire population. All of these things involve effective lighting, while the fuel situation demands the utmost economy.

In the past the Government's interest in industrial lighting was principally concerned with the prevention of accident and conservation of eyesight. To-day, it is imperative that each worker produce to the maximum and that many of them do so at times and in places where daylight is absent or insufficient. In this connection it is necessary that materials be conserved, especially those that are available in limited quantities; that the fuel consumed for power and heat be utilized effectively. All this depends upon good illumination. Manufacturers as a class, and especially the smaller ones, have not fully recognized the value of good illumination, but either through inertia or false economic ideas, have viewed lighting as a necessary but unwelcomed expense.

It is, therefore, nationally important that an effort be made to improve industrial lighting. The movement to secure the wide adoption of lighting codes, as taken up by the Divisional Lighting Committee (under the Advisory Commission of the Council of National Defense), is a step in the right direction. But efficient manufacturing generally needs better lighting than can be prescribed to insure safety. The Society and its members are leading in a movement for better industrial lighting. Our Committee on Lighting Legislation has been doing much of the pioneer work. Let us accelerate it as much as possible.

Protective lighting is still of unusual importance, and will be so long as there are among us murderous and desperate enemy sympathizers who are seeking secretly, under cover of darkness, to interfere with our manufacturing and other activities. A slight explosion at a vital part may temporarily stop a large industrial plant or transportation line. With our complex institutions, protective lighting is likely to retain a certain importance, even after the war; now it is indispensable. The pamphlet on protective lighting, prepared by our Committee on War Service and published by the War Department, is one of our important contributions toward winning the war. It is the best available treatise on the subject. By advocating the application of the principles and practices described therein, each of us can help defeat sneaking attacks of our enemy.

In this connection, we must remember that street lighting always has been in the past a protective measure, and while in recent years a small part of it has acquired certain ornamental and advertising features, street lighting as a whole is still protective lighting, and as such cannot be reduced or eliminated without accident and criminal hazard. By warning those in authority, we may be instrumental in preventing disorder and even disaster. Such things come without warning. The prevention is not spectacular and may never be recognized. The occasions for regret have been unfortunately frequent.

The congested condition of our railways has increased highway traffic, so in a sense, anything that makes street and road travel safer has some bearing on the war. Certainly it has on the country's welfare.

Our Committees on Lighting Legislation and Automobile Headlighting Specifications have, by invitation, been co-operating with certain New York State officials on the automobile headlighting problems. While the result has not come up to our hopes in all respects, and on account of various conditions has fallen short of our ideal, we have reason to believe that the roads of that state will be safer as a result of our effort. Furthermore, our Committees have learned much as the result of the investigation, so that we should be able soon to draft a code which can be offered to all our commonwealths as a working guide for protective regulations. It will be of permanent value to the country

if we can succeed in establishing headlight regulations on a definite and determinable basis.

At the request of the United States Fuel Administration, received through the National Committee on Gas and Electric Service, our Committee on War Service has been studying the possibilities of fuel conservation in connection with illumination. The elimination of extravagance and waste we could heartily subscribe to as tending to develop the art of lighting and put it on a more stable basis. We have looked upon the restriction of useful lighting, even for commercial or advertising purposes as a destructive measure, containing possibilities of injury and injustice. However, when advised of the necessity, we have heartily co-operated, even to an extent which may pull down part of the structure of lighting practice, of which we are so proud. But when we balance the lives of American soldiers against lighting comforts and refinements—as the Fuel Administration tells us we must—there is but one answer.

We believe that no curtailment of useful industrial or protective lighting can be made, without loss of production or danger to operatives. Reduction of useful commercial lighting will work some hardship and a relatively small fuel saving. So that it seems apparent that the end sought is to utilize the psychological effect in securing economy in other fuel applications.

To some of us, at least, the psychological value seems likely, in the long run, to be questionable. But as loyal citizens, we must support the Government authority, and our Committee has given its hearty co-operation to the Fuel Administration, and endeavored to help them make the desired saving in such a way as to minimize any hardship on the public interest. Let us all, as members, do what we can to facilitate the difficult tasks which confront the Fuel Administration.

There are many other activities of war service which have been undertaken or are contemplated, but which I cannot mention at the present time. These will be sufficient to give you an idea of what your officers have been doing, as your representatives. I hope it will not only suggest opportunities where each one of you can help—and also indicate the patriotic need for your support given through the Society.

I am sure you will all agree with me that we have much yet to

do in putting our art to work for winning the war. We are limited, however, by the size of the Society and by the relatively small funds available. Increased membership would unquestionably enlarge our opportunities and our influence in securing recognition of the possibilities of lighting.

I am somewhat familiar with the accomplishment of other organizations and am satisfied that, relatively, the Illuminating Engineering Society has made a splendid showing. This is very largely due to the reputation which we have established, the cordial co-operation of friendly organizations, and the devoted service of some of our Committees. Each member can be sure that his membership is in itself a patriotic contribution. By securing new members, we can contribute further. Many of our members are already in the service and the number to be carried on the roll without payment of dues will undoubtedly increase considerably during the coming year.

We have a pride in the hundred members who have already entered the service. Some of them, as fighting men and some in capacities which enable them to utilize their illuminating engineering attainments. Already they are beginning to appear on the casualty lists—two of them have made the supreme sacrifice. How better can we honor them than by carrying cheerfully their burdens in the Society, and by making the lighting art more serviceable?

If you believe in the good, patriotic work which the Society is doing, let the new administration have your support, even more actively than in the past. Your officers have planned for still more effective service in the future, based upon the past year's experience.

One proposed feature which I would particularly like to call to your attention is a reorganization of the Committee on War Service, whereby the entire technical knowledge and experience of our membership will be made effectively available to the Government.

When the Committee was originally appointed, a little over a year ago, its members were selected with reference to the particular problems which had then been referred to the Society. Later, we found it desirable to refer to the Committee, work of an entirely different character, requiring the service of men not

on the Committee and with regard to which some of the original members were not qualified to act effectively, so additional members were appointed from time to time, and the services of men not on the Committee were secured. The Committee then became too large for most effective action, while men who made important contributions were not properly recognized. To meet this situation it is proposed to appoint, for the coming year, a small executive or "steering" committee, carefully selected for their broad acquaintance in the Society and their responsibility, while all members of the Society will be considered to be on the Committee on War Service.

When a problem is submitted to this Committee, its executive committee will appoint a special sub-committee, composed of those best qualified to handle that particular matter. Any report will be signed by the sub-committee and countersigned by this executive committee. On the completion of the work, the sub-committee will automatically disband. It is possible that several such sub-committees will be working on different problems at the same time. The Council will presumably hold the Committee on War Service responsible for the acts of any of its sub-committees. Besides avoiding the difficulties of the past, this literally makes the entire membership of the Society available to the Government, without delay or complication. I am sure this plan, which has just been ratified by the Council, will appeal to you all, and that the Committee can look to you with confidence for your support, when the call comes.

In conclusion let me extend my personal appreciation to all the officers, committeemen and members of the Society for their cordial support. I am humbly conscious of the small part I have played and of the large part which you have contributed. I am proud that I can retire from my stewardship, leaving the Society in a healthy and prosperous condition, and engaged in a noble and effective work. I know that you will all extend to my honored successor the same loyal and hearty co-operation that the Society may go on to new and greater achievements.

INAUGURAL ADDRESS* OF PRESIDENT GEORGE A. HOADLEY.

There never has been any question as to this meeting's being and belonging to the administration that is just closing. It is the rounding up of the work of that administration, and I call you to witness that we have never had a rounding up that has been more complete, more compact, more compressed together into an active day's work, than we have had this year. I don't know how anyone can go from this convention, without the feeling that the past year's work has been brought to a successful close. It is the close of the twelfth convention. Let us make the next, the thirteenth, for the Hun.

I have always been proud to belong to this Society, for the reason that it seemed to me that its work was altruistic. The work that has been done, and is being done, is for the public. That is the great object that we have in view. And there is also this to be considered: Is there any especial work that has ever been taken up, that has not been carried to a successful issue? We have considered the matter of domestic lighting. We have heard no word of that to-day. Why? Because we worked that out and have given directions for domestic lighting that have proved successful. Street lighting has been considered. We have seen our men go out on the streets of New York City, and examine the lighting there—in Philadelphia, and the other cities—see what was needed, and produce results. That has not been mentioned to-day. To-day, we have the lighting that is required for the present, and these questions will be studied, examined, investigated, and settled, as the others have been.

I feel very greatly the honor that you have conferred upon me. I want definitely to express that I feel a great deal of satisfaction, sir, in holding this gavel in my hand. I first held it something like four years ago, I believe, when, at the convention in Pittsburgh, I presented it, with the good wishes of the Society, to the Presiding Officer. There are many things in it that have a historic interest. I hope I shall be permitted to use it, but in no way that will not be satisfactory to you.

* An address presented before the 12th Annual Convention of the Illuminating Engineering Society, New York, N. Y., October 10, 1918.

I don't believe that I am a man who has many new ideas. But I think I am an excellent man to receive ideas, to consider them, to hand them over to the Council, to talk them over, and then to get the most good out of them.

Gentlemen, let us look forward to a successful year.

REPORT OF THE COMMITTEE ON PROGRESS.*

A man will scan a cloudy sky,
In hopes it may grow bright,
Yet if he to the sun should fly
He'd only ask for light,
Light, more light!

(After the Norwegian of Per Sivle, translated by H. G. Chapman.)

INTRODUCTION.

A review of recorded information regarding sources of light, the lighting industry and other factors germane to illuminating engineering shows that since the last report of this committee there has been progress in spite of the fact that the prosecution of the war is absorbing the interest and activities of practically all classes of workers throughout the country. The very necessity of continuous night work in factories together with the demand for the highest precision and largest output has shown conclusively the value of lighting conditions, and their effect on manufacture.

Attention is being called¹ to the importance of having qualified engineers employed to plan the lighting for new buildings in industrial plants, and a recent survey² has shown that experimentation is being carried on in numerous instances in order to determine the very best type of installation for a particular condition. Many plants have revised³ their lighting systems during the past year purely as a war measure. The results of improved lighting

* An annual report prepared for the Twelfth Annual Convention of the Illuminating Engineering Society October 10, 1918, New York, N. Y.

The papers and discussions included in our own TRANSACTIONS are not reviewed in this report, it being taken for granted that members keep themselves advised of the contents of the TRANSACTIONS.

¹ *Elec. Rev.* (U. S.), June 1, 1918, p. 907.

² *Elec. Wld.*, June 8, 1918, p. 1194.

³ *Jour. of Elec.*, June 1, 1918, p. 550.

can be seen in larger and better production, fewer accidents, reduced spoilage, and steadier labor.

In other directions, however, the tendency has been toward economy in the use of light and war restrictions have had much to do with reduced street, show-window, and display lighting. The larger cities report very little if any increase in the number of street lamps and in at least one case apparently necessary extensions were refused sanction by the city council.

It is surprising to note the variety of designs which have been put on the market for the combination indirect and semi-indirect lighting fixture. Originally in two parts, a lower diffusing globe and an upper reflector, all sorts of modifications have come out, the latest having the two parts in one piece, and in another case even the bulb of the lamp itself has been utilized. In a similar way there has been a big development in flashlights, small searchlights, and automobile lights. Little has been reported of foreign activities and this mostly on the theme of restricted lighting. In view of the fact that some countries like Denmark and Holland have been forced owing to coal shortage, to come down to the use of candles and oil lamps this is not surprising. Nevertheless some research work is apparently still going on in Germany and it is possible that there have been developments of importance, description of which has not been permitted.

The total eclipse of our main source of light was expected to furnish an opportunity for much new information regarding this most vital factor in human existence. There has not as yet been time to publish the analysis of the results of observations but some interesting points have been reported. At Goldendale⁴ where the observers of the Lick Observatory were located, the sky was completely covered with clouds all day until just before the eclipse when a rift appeared which opened up so that a very small area of the blue sky free from clouds had the sun at its centre exactly at the middle of the total phase. This region cleared not more than a minute before the beginning of totality, and clouds again covered the sun less than a minute after the passing of the shadow. All the instruments and all of the observers were ready and their program went through as planned.

The thanks of the committee are due to those who have fur-

⁴ *Science*, July 12, 1918, p. 34.

nished data and to the publishers of periodicals whose information has been freely used.

Respectfully submitted,

F. E. CADY, *Chairman*;
E. F. KINGSBURY,
W. B. LANCASTER,
R. FF. PIERCE,
T. W. ROLPH.

GAS.

The successful amalgamation of the two largest gas societies in this country, the American Gas Institute and the National Commercial Gas Association was accomplished when the American Gas Association was formed in New York City, June 6.⁵ The importance of this movement on the development of the industry can only be conjectured, but any step looking toward unity of thought and action would seem to be particularly helpful and appropriate at this period in the history of the country. There will be established a closer co-operation between gas manufacturers and those manufacturing gas appliances and apparatus.

Manufacture.—The war has caused such a shortage in coal supply that most European countries are experiencing⁶ great difficulties in keeping up the manufacture of gas. It is reported⁷ that a supply of monazite sand from the Travancore district of India is now being obtained by an American company. Possession of this property before the war by German manufacturers enabled them to figure prominently in the world's supply of thorium for the making of mantles.

An English inventor⁸ has brought out what is called a new gas of 350 B. t. u. per cubic foot (3,110 cal. per cu. m.) or less, and a considerable agitation as to the merits of his proposals has resulted. He claims the possibility of increasing the efficiency of utilization of the B. t. u., in good quality, clean dry coal from 50 to 83 per cent. Another new development⁹ in gas manufacture is the production of gas from straw refuse on the big ranches of northwestern Canada. A retort has been invented

⁵ *Gas Record*, June 12, 1918, p. 363.

⁶ *Gas Age*, Jan. 1, 1918, p. 5.

⁷ *Gas Jour.*, Nov. 30, 1917, p. 386.

⁸ *Gas Age*, April 1, 1918, p. 293.

⁹ *Gas Jour.*, Nov. 13, 1917, p. 326.

for carbonizing straw and other cellulose material thereby decomposing them into combustible gases, tars and ammonia. A ton (0.907 metric ton) of straw will give between 11,000 and 12,000 cu. ft. (311 and 340 cu. m.) of gas of a calorific value of approximately 400 B. t. u. per cubic foot (3,560 cal. per cu. m.). From every ton of straw there is obtained 6 to 8 gallons (22.7 to 30 liters) of tar and ammoniacal liquor. In the three prairie provinces of western Canada only, it is said 20,000,00 tons (18,140,000 metric tons) of straw are available annually which could be used to produce 140,000 million cu. ft. (3,960 million cu. m.) of gas. Another radical departure in the production of gas is reported from France.¹⁰ A large tonnage of spoiled flour was salvaged from a torpedoed vessel. The flour was useless for bread-making, and it was turned over to the gas works and distilled. From 5,280 pounds (2,400 kg.) of flour, 11,200 cu. ft. (317 cu. m.) of gas and 1,584 pounds (718 kg.) of coke were obtained, the latter leaving practically no ashes when burned. Tests have been made¹¹ of the effect on the lighting and heating value of a mixture of artificial and natural gas when the relative amounts of the two gases in the mixture are changed. The results indicate that with a percentage of natural gas from 10 up to 75, the open-flame candlepower of the mixture was maintained. With a constantly decreasing artificial gas content, but a rising heat value, the ratio of the candlepower to the heat units remained nearly constant up to a critical point where the percentage of the natural gas was about 70.

Accessories.—In England, the birthplace of the open-flame gas burner, the use of the latter has diminished¹² to such an extent that of gas manufactured “not 5 per cent. of the whole output is now used for direct illumination” in such burners, according to a statement by a member of the gas engineering profession in a presidential address before the Institution of Civil Engineers. It has been pointed out¹³ that a lowering of the B. t. u. requirements for gas in order to permit of greater toluol recovery will have a very deleterious effect on gas lighting by open-flame burners. Particularly is this true in New England where the Massachusetts standard fixed at 528 B. t. u. (4,700 cal. per cu. m.)

¹⁰ *Gas Age*, Jan. 1, 1918, p. 7.

¹¹ *Gas Industry*, Jan., 1918, p. 19.

¹² *Nature*, Nov. 29, 1917, p. 255.

¹³ *Gas Record*, Feb. 27, 1918, p. 124.

is claimed to be the lowest thus far specified for any state. It has been estimated that in this part of the country there are two or more open-flame burners for every one of the mantle type.

A new gas burner¹⁴ introduces directly to the inner surface of the inner cone of the bunsen flame, a secondary supply of heated air independent of that which forms the mixture in the tube. It is claimed that a more perfect gas and air mixture is obtained. The use of large gas lamps containing as many as fifteen mantles is increasing.¹⁵ A new system of gas utilization has been developed¹⁶ by an English inventor. He has devised what is called a pressure balance and is said to have obtained a candlepower of from 130 to 150 with a small gas mantle and a consumption of less than 3 cu. ft. (0.085 cu. m.) per hour.

Calorific Standards.—After a careful study of the tests made by the inspection department, the Gas Commission of Massachusetts has tentatively decided¹⁷ to adopt the French standard, viz., 528 B. t. u. (4,700 cal. per cu. m.) as the calorific standard for gas in Massachusetts. Previous to issuing the order, tests were conducted for six months in nineteen gas plants. The question of a universal adoption of 528 B. t. u. (4,700 cal. per cu. m.) as the standard for gas throughout the country has been raised¹⁸ by the United States Fuel Administration. It is pointed out that this would mean the doom of the old open flat-flame burner, as with the elimination of the candlepower requirements such a standard is ideal for incandescent gas lighting. The purpose of such an order would be to conserve oil. Agitation for a universal calorific standard and the abolition of the candlepower standard is also being carried on¹⁹ in England.

At the request of the U. S. Ordnance Department the 600 B. t. u. (5,340 cal. per cu. m.) required average in several New Jersey cities was lowered to 570 (5,070 cal. per cu. m.), it being understood that the permit would be maintained²⁰ as long as the government finds it necessary in order to obtain a sufficient supply of toluol. Similarly²¹ at the request of the Federal Government

¹⁴ *Gas Jour.*, August 21, 1917, p. 325.

¹⁵ *Amer. Gas Eng. Jour.*, Feb. 15, 1918, p. 165.

¹⁶ *Gas Jour.*, Sept. 25, 1917, p. 563.

¹⁷ *Amer. Gas Eng. Jour.*, Dec. 8, 1917, p. 533.

¹⁸ *Gas Age*, June 15, 1918, p. 582.

¹⁹ *Gas Jour.*, June 11, 1918, p. 476.

²⁰ *Gas Record*, Feb. 13, 1918, p. 91.

²¹ *Gas Jour.*, Nov. 27, 1917, p. 423.

gas companies in the First District of the New York Public Service Commission may elect to operate under a heating standard for the duration of the war and three months thereafter. An interesting fact has been brought out that in New York City only 20 per cent. of the gas consumed is used for open-flame lighting purposes. At Minneapolis²² the Council agreed to a reduction in the candlepower standard from 15 to 10, but no reduction was made in the heating standard. This action is to last for the period of the war or as long as the company is manufacturing toluol for the government.

Experiments by a foreign investigator²³ indicates that illuminating gas exhibits no generally poisonous character towards plants.

Acetylene.—In Switzerland experiments have been reported²⁴ on the result of mixing acetylene with coal gas with a view to the replacement of the former gas mixture made of 67 per cent. of oil gas and 33 per cent. of acetylene. It was found that a 1 to 1 mixture of the coal gas with the acetylene gave the same illuminating power as the oil gas combination. Two to three liters of the mixture were required to obtain one candlepower. It was also shown that the mixed gas could be put under pressure of 9 atmospheres and heated to 100° C. without danger. For lighting railway trains no alterations in the equipment are necessary. In Denmark the government Commission has approved²⁵ some models of acetylene lamps and a large number are now being constructed. Arrangements are being made with Norway and other countries to import enough carbide to supply people who have no gas, electricity or kerosene.

A great impetus has been given²⁶ by the war to the use of acetylene for lighting purposes. A large number of tanks containing the compressed gas are being used in portable hospitals and in first aid stations. Acetylene lamps are also being used for signalling purposes on the principle of the heliograph and the same gas is used for flare lights to illuminate camps, dugouts, trenches, and for directing troops at night along the road. Small portable lamps are being made in large numbers for use in Cuba

²² *Amer. Gas Eng. Jour.*, July 6, 1918, p. 18.

²³ *Gas Jour.*, Oct. 9, 1917, p. 63.

²⁴ *Jour. of Acetylene Ltg.*, March, 1918, p. 301.

²⁵ *Sci. Amer.*, Dec. 22, 1917, p. 471.

²⁶ *Jour. of Acetylene Ltg.*, Jan., 1918, p. 240.

and other places where the fire regulations are not so strict as in this country. The objection to acetylene miner's lamps due to their susceptibility to drafts and to concussion from blasting has been eliminated by the use of a wind shield and by the addition of a steatite ring placed around the base of the flame and heated by it. This serves to re-ignite the gas in cases of momentary interruption. The old Derby wharf light located off the city of Salem, Mass., has been equipped²⁷ with an improved automatic acetylene apparatus. Six tanks are provided which are automatically cut in, thus requiring attention only once in six months.

INCANDESCENT LAMPS.

Manufacture.—The fact that tungsten is used not only for incandescent lamps but also in connection with the manufacture of steel makes its availability a matter of considerable interest. This is particularly true since the advent of the war has curtailed the communication which formerly permitted the importation of this mineral from any part of the world. According to reports from the U. S. Consul at Canton²⁸ there is a rapidly growing exportation of Wolframite from China. Much of it comes from a district so remote that the ore is carried on human shoulders for a distance of 60 miles (97 km.), then 80 miles (125 km.) by junks, and from there on by rail. It is also reported²⁹ that the Wolframite deposits recently discovered in Brazil are very rich and their location favorable to exportation.

Further particulars are now available of the process³⁰ for producing a continuous tungsten crystal as a filament to be used in place of the ordinary drawn wire in glow lamps and referred to in last year's report. A drawn tungsten wire which in the initial cold state has a structure made up of parallel fibers begins to recrystallize after a filament is heated to incandescence. When this recrystallization is complete the extensibility and flexibility imparted by the drawing process disappear making the filament liable to breakage from shocks. It is the purpose of the new process to preserve these properties both in the cold and hot states. The crystallized filament is so malleable that it can be wound

²⁷ *Jour. of Acetylene Ltg.*, Nov., 1917, p. 180.

²⁸ *Sci. Amer.*, Dec. 1, 1917, p. 401.

²⁹ *Elec.* (Lond.), Nov. 16, 1917, p. 253.

³⁰ *Elec. Rev.* (Lond.), Dec. 7, 1917, p. 540.

around the smallest mandrel and it maintains this property even after burning for an extended period. Tests have shown³¹ that these filaments have remained mechanically strong even after 1,200 hours burning with no black deposit appearing on the inside of the lamp bulbs. The radiant properties are said to be very much the same as those of pure tungsten wire owing to the small amount of thorium oxide used.

A German inventor has taken out a patent³² relating to tungsten lamps which aims to overcome the deteriorating effects of substances used to prevent the blackening of the bulb by operating the filament in an atmosphere of oxygen at low pressure. It is stated that at low pressure the oxygen does not noticeably attack the hot filament but that in the colder zones of the lamp it oxidizes the vaporized tungsten, producing a colorless and non-volatile deposit which does not increase the pressure and tends to prevent discharges through the gaseous medium. The pressure of the oxygen gas should be not more than 0.005 mm. of mercury and not generally less than 0.001. This effect may be obtained by introducing into the interior of the lamp substances such as manganese super oxide, or barium chlorate which at a temperature and under the conditions prevailing in the lamp when in operation give up continuously as much oxygen as is consumed by the oxidation of the vaporized tungsten. It should be noted that this procedure has been common practice in this country for several years. It may be interesting to add that the vacuum ordinarily obtained in tungsten lamps is better than 0.0005 mm.

Despite the present long life (1,000 hours) of tungsten lamps, a new arrangement of filaments in the bulb has been proposed,³³ which according to the inventor should lengthen the life of the lamp to three times that ordinarily obtained. Twelve filament sections are provided, each giving 25 cp. and burning independently of each other. Four are lighted at once when the lamp is first turned on. When one breaks, a spring in the lower supporting wire causes contact with a second section. In addition to the eight sections thus interrelated, four more sections, on an independent circuit, may be put in service by pulling a chain.

³¹ *Zeit. Ver. deutsch. Ing.*, Jan. 12, 1918, p. 15.

³² *Elec. Wld.*, Nov. 3, 1917, p. 854.

³³ *Elec. Rev. (U. S.)*, May 25, 1918, p. 891.

Carbon Lamps.—A circumstance which seems unexplainable to the ordinary engineer is the fact that in spite of the cheapness and superiority of the tungsten filament lamps, the use of carbon filament lamps still shows an increase.³⁴ The Government³⁵ retains its carbon lamp schedule in the "Standard Specifications" "because these lamps still properly find a considerable application particularly in service where the renewal cost of tungsten lamps would be excessive on account of an unusual amount of theft or breakage." However, last year,³⁶ carbon lamps represented only 12 per cent. of the total sales of incandescent lamps and the pressure being brought to bear on the saving of energy in all possible directions may have a decided effect³⁷ in the direction of the use of the more efficient type of lamp.

Portables.—For all classes of work where a portable lamp is required and electricity is available for charging purposes, a compact arrangement has been developed.³⁸ It consists of five storage cells together with two properly guarded 12-candlepower lamps with reflectors and 11-ft. (3 m.) leads. One of the lamps will run constantly for 24 hours on one complete charge of the battery, or both lamps will run for 10 hours. The cells are contained in a small steel box and the whole outfit weighs only 40 pounds (18 kg.).

Properties.—It is understood that when a value is given for the life in hours of an incandescent lamp, this means the average life of a fair number of such lamps. An analysis of renewal conditions based on a knowledge of percentage failure at various hours of life of a large number of lamps has led³⁹ to the conclusion that it is not justifiable to judge the life performance of an installation of incandescent lamps from the resultant renewal data unless the latter covers a sufficient period of time.

Abroad a series of tests have been made⁴⁰ for the purpose of determining the relative costs and merits of gas-filled tungsten incandescent lamps and arc lamps for both interior and exterior lighting. The author states that the tungsten lamp may compete

³⁴ *Elec. Wld.*, Nov. 3, 1917, p. 849.

³⁵ Circular No. 13, Bureau of Standards, Apr. 13, 1918.

³⁶ *Elec. Rev.* (U. S.), May 18, 1918, p. 828.

³⁷ *Elec. Rev.* (U. S.), July 20, 1918, p. 95.

³⁸ *Sci. Amer.*, Sept. 29, 1917, p. 225.

³⁹ *Elec. Wld.*, Jan. 12, 1918, p. 93.

⁴⁰ *Zeit. f. Deut. Eng.*, July 28, 1917, p. 625; see also *Sci. Abs.*, Oct. 31, 1917, p. 392.

with open or enclosed arcs burning plain carbons in the lighting of interiors; and with flame arcs in exterior lighting.

An extended investigation has been carried out⁴¹ on the effect of the form of the voltage wave on candlepower, efficiency and life of tungsten filament lamps operated on alternating current. In order to magnify the effects, 20- and 25-watt lamps were used. At the end of 1,000 hours burning the average candlepower of lamps burned on a sine wave was slightly higher than those burned on a peaked wave. Similar results were obtained in the efficiency test. In the life performance, excessive breakage occurred on the peaked wave, amounting to nearly five times that on the sine wave.

The subject of "over-shooting" of the temperature and hence the candlepower of tungsten lamps has been studied at some length in the past. Recently there appeared a report of an investigation⁴² on the amount of "over-shooting" in current, when metal filament lamps are thrown in circuit. It was found that the initial current does not rise to a value greater than normal proportionate to the ratio of the hot to cold resistance. Various factors decrease the efficiency voltage at the lamp, thereby preventing the current from rising to a high value. The higher-wattage lamps do not "over-shoot" to so high a percentage above normal as the low-wattage lamps, and the "over-shooting" of vacuum lamps is slightly less than that taking place in the gas-filled type. It was found that with the circuit breakers and fuses of proper rating and set correctly, there was no reason for trouble when throwing in a circuit containing gas-filled tungsten lamps.

Tests have been made⁴³ to determine what conditions favor flickering with a periodically varying source of light, the lowest frequency permissible with modern metal filament lamps, and the greatest voltage variation permissible on either direct current or alternating current systems of a frequency too high to produce flickering. The fact that the frequency at which flickering ceases is, over wide limits, proportionate to the logarithm of the intensity of illumination, was confirmed. The permissible voltage variation was found to depend upon the frequency. The lowest

⁴¹ *Elec. Rev.* (U. S.), March 23, 1918, p. 542.

⁴² *Elec. Wld.*, March 2, 1918, p. 459.

⁴³ *Elek. Zeit.*, Sept 13, 1917, p. 453.

frequency at which flickering is avoided was about 30 cycles per second.

Specifications.—The Government has again held a conference⁴⁴ with the engineers of the incandescent lamp industry for the purpose of revising the specifications for this type of lamp. For the first time the new type of gas-filled lamp is referred to. It is interesting to note that in Switzerland also ⁴⁵ revised specifications for incandescent lamps have been worked out. Lamps are to be graded according to watts. For metal filament lamps two grades of specific consumption are recognized, one for 800 hours life and the other for 1,600 hours life. For gas-filled lamps only the 800-hour life is considered. It is stated that the relations between pressure, candlepower, watts, useful life and tolerance are based on exhaustive tests partly carried out in the laboratories of the Association Suisse des Electriciens and partly in other laboratories. The following data must be marked on the labels: manufacturer, voltage, consumption in watts, mark of the Association, and at the desire of the purchaser, mean spherical candlepower and mark of the purchaser. The Ulbrecht sphere is specified for the determination of candlepower.

ARC LAMPS.

Flaming Arc Lamps.—The flaming arc lamp which uses calcium fluoride as its extra light producing constituent has a decidedly yellow appearance. The addition of uranium as an ingredient, together with the calcium fluoride results in a snow white arc which is said to be exceptionally rich in blue and violet rays, and to have considerably more photographic power than an arc in which the rare earth fluorides or titanium oxide are used.⁴⁶ This uranium arc has about six times as much ultra-violet radiation as the ordinary iron arc used in medical work, and hence its use for medicinal purposes is suggested. Efforts are continuously being made to extend the sphere of usefulness of the arc lamp. Thus the white flaming arc has been adapted for use in moving picture projection in those cases where only alternating current is available. A more uniform light distribution is obtained and the noise is much reduced.

⁴⁴ *Sci. Amer.*, Oct. 13, 1917, p. 267.

⁴⁵ *Elec. (Lond.)*, Oct. 26, 1917, p. 115.

⁴⁶ *Elec. Wld.*, Nov. 24, 1917, p. 1002.

Motion Picture.—It is claimed⁴⁷ that the correct ratio of the diameters of the positive and negative electrodes has an important influence on the steadiness of the arcs used for cinematograph work, and that a ratio of 4 to 1 is right. Further, by putting a second coating of nickel over the copper plating of the negative carbon, all flickering and sputtering can be avoided. As the present vertical arc lamps used in moving-picture projection work were found to be unsatisfactory when used with a new color photography development⁴⁸ an improved arc has been worked out for this special purpose. It is a horizontal magnetically controlled arc which is claimed to give approximately one-third more light for the same current than standard vertical arcs and may be relied upon for consistency of position of the source.

An improvement in the carbon holders⁴⁹ for arc lamps enables the use of any size carbon in the lower grip, by means of an easily adjustable clamp. A lateral motion is also provided for.

Vapor Lamps.—The neon vapor tube when lighted shows a predominance of red radiations. To obtain a light more suitable for general purpose it is proposed⁵⁰ to correct this reddish effect by the use of two tubes. In one are introduced a few drops of mercury which are then volatilized with alternating current until the neon radiations disappear. The result is a greenish light. The green radiations of this corrector tube are then added to the red radiations of an adjoining neon tube. It has been found that if the red tube and the greenish corrector tube have the same diameter and the same current is passed through both, the green tube should be about twice as long as the red one to get the proper proportioning of the colors.

An improved form of quartz mercury vapor lamp has been brought out,⁵¹ which is of the class known as the "hot anode" type, differing from other designs in that no mercury chamber is used at the anode end, the cathode containing practically all the mercury, the pressure forcing the mercury back into this end continuously. The anode is of tungsten very highly purified to prevent discoloration of the tube. The lamp may be operated in

⁴⁷ *Illum. Eng.* (Lond.), Nov., 1917, p. 295.

⁴⁸ *Moving Picture World*, Oct. 6, 1917, p. 61.

⁴⁹ *Elec. Rev.* (U. S.), July 20, 1918, p. 109.

⁵⁰ *Elec. Wld.*, Sept. 8, 1917, p. 469.

⁵¹ *Elec. Wld.*, March 2, 1918, p. 491.

any plane and therefore permits of application to many types of equipment. The lamp when starting takes 8.5 amperes at 220 volts but runs at 3.5 amperes.

Research.—Work on the carbon arc operated in an atmosphere under pressure is still being carried on,⁵² the latest experiments dealing with atmospheres of oxygen, nitrogen and the gaseous products of the arc itself. It has been found that there is a relatively small increase in candlepower with increase in pressure for the oxygen atmosphere. In nitrogen under pressure the arc is considerably steadier than in air, and there is a small increase in candlepower with increase in pressure.

LAMPS FOR PROJECTION PURPOSES.

Flashlights.—The extensive use and importance of flashlights is indicated⁵³ by the demands of the Navy department which in a single demand asks for 182,000 dry flashlight batteries and 68,000 flashlights without batteries. The shortage of materials used in dry cells and small accumulators for pocket flash lamps has stimulated in Germany⁵⁴ the development of the hand operated magneto. Lamps thus equipped are more expensive than the ordinary type, but of course they do not need the battery charging or replacement. A type weighing only one pound will provide light for three minutes with one release of the spring which can be wound with a pressure of the thumb. A heavier apparatus, weighing five pounds and requiring both hands to wind the spring, will furnish light for ten minutes on one winding. In these types the armature rotates; in another lighter type the fields rotate. A moderate sized apparatus for use with bicycles weighs three pounds. Evidence of the use of these magnetos is indicated in the report of the finding of one of the lamps and apparatus on a battle field of France.⁵⁵ A new⁵⁶ battery flashlight is made in the shape of a bullet 6 in. by $1\frac{5}{8}$ in. (152 by 41 mm.) in dimensions.

Searchlights.—A new form of hand lamp of the projection type⁵⁷ combines a reflector and an auxilliary deflector in such a

⁵² *Elec. Zeit.*, Dec. 6, 1917, p. 573.

⁵³ *Elec. Wld.*, June 29, 1918, p. 1401.

⁵⁴ *Sci. Amer.*, Jan. 19, 1918, p. 67.

⁵⁵ *Elec. Rev.* (Lond.), Oct. 26, 1917, p. 390.

⁵⁶ *Elec. Merch.*, Dec., 1917, p. 342.

⁵⁷ *Sci. Amer.*, Jan. 26, 1918, p. 92.

way as to give a concentrated beam extending for 500 ft. (150 m.), while nearby objects are illumed by a diffused light with a minimum of glare. It consists of a light source of high candle-power surrounded within its most useful degrees by an annulus of parabola for beam projection. The glareless and diffused general illumination is secured by transmitting direct light through as well as reflected light from the outer surface of a translucent screen, which is light collecting by a spherical reflector adjacent to the aperture of the beam reflector.

The battery searchlight operated on dry cells is being constantly improved.⁵⁸ The combination of gas-filled tungsten lamp and properly designed reflector has made it possible⁵⁹ to produce an instrument with a range of 200 ft. (60 m.) up to $\frac{1}{2}$ mile (0.8 km.), operating on 6 volts. Equipped with a 7.5-in. (191.1 cm.) adjustable focus, single shell reflector, a photometer test indicated over 400,000 equivalent candlepower.

Automobile Lamps and Headlamps.—The extent to which the demand for electrical lighting equipment for automobiles has grown is indicated by the fact⁶⁰ that there are said to be in operation at the present time some 4,000,000 pleasure vehicles, a large majority of which have a unit power plant to furnish electrical energy for lighting, starting and ignition. In order to make the adjustment less difficult it has been suggested⁶¹ that the ideal form of filament for auto headlight lamps would be a duplex helical filament with one helix lying in the focal axis and inside another helix. It is claimed that such a filament would not require so sensitive an adjustment as is now necessary for the best light distribution. Headlamps for automobiles with "V" shaped doors which blend with the contour of radiators of special design show the extent to which specialization⁶² is being carried in this direction.

A novel arrangement devised⁶³ to keep the light from an auto within legal limits has been described. It consists of an all metal cellular attachment, containing more than 9,000 small metal reflectors. This attachment is put in the upper half of the head-

⁵⁸ *Elec. Record*, June, 1918, p. 31.

⁵⁹ *Sci. Amer.*, March 30, 1918, p. 271.

⁶⁰ *Elec. Record*, June, 1918, p. 66.

⁶¹ *Elec. Rev.* (U. S.), Dec. 22, 1917, p. 1060.

⁶² *Elec. Record*, June, 1918, p. 37.

⁶³ *Sci. Amer.*, June 29, 1918, p. 583.

lamp behind the regular glass door and is said to deflect those rays which normally rise above the 42-in. (107 cm.) level. It is claimed that the device transmits 93 per cent. of the lamp's candle-power. The New York State headlight law passed last year demands a light strong enough to reveal objects at a distance of 200 ft. (61 m.) ahead, and that no dangerous or dazzling light when measured 75 ft. (23 m.) or more ahead of the lamp shall, at the left of the axis of the car, rise above a level of 42 in. (107 cm.). It has been suggested⁶⁴ that a simple way of making an ordinary clear glass headlight conform to this requirement is to adjust the focus of the bulb so as to give a fan-shaped pencil of emitted and reflected rays. Then paint the bulb a solid dark green over that part of it through which would ordinarily go those rays which project into space on the inroad side of the axis. Another method of accomplishing this result is provided⁶⁵ in a lamp whose bulb is partly silvered, partly frosted, and partly clear, the silvering taking the place of the green paint. A different method of glare control is found⁶⁶ in a device consisting of three nickel-plated wings pivoted at the socket so that they can be made to fold around the bulb in such a way as to cut off all except the light coming directly through the tip. There have also been devised spectacles⁶⁷ with the left part of each lens made of colored glass to aid the driver in avoiding the glare caused by approaching undimmed headlights.

In St. Louis⁶⁸ the question of whether auto headlights are too dim or glaring is decided by measurement using a standardized apparatus. It consists of a cabinet 5 ft. (150 cm.) high by 3 ft. (90 cm.) wide and 2½ ft. (75 cm.) deep. An opening in the front admits light from the headlights. This light falls on a test curtain within the cabinet, the curtain being observable through a peep hole in the side of the box. The apparatus was standardized as follows. After selecting a car in which the lights were considered just right, the machine was placed at a measured distance from the cabinet and the headlights were directed upon the slot. Back of the curtain was an electric lamp regulated by a rheostat until the illumination on the curtain balanced that pro-

⁶⁴ *Sci. Amer.*, Sep. 8, 1917, p. 178.

⁶⁵ *Elec. Record*, June, 1918, p. 72.

⁶⁶ *Illustrated Wld.*, March, 1918, p. 117.

⁶⁷ *Sci. Amer.*, April 13, 1918, p. 348.

⁶⁸ *Sci. Amer.*, Jan. 5, 1918, p. 9.

duced by the automobile headlamps. In testing the headlights of a car the machine is placed at a standardized distance and observation through the peep hole will determine whether the lights are too strong or too dim, the lamp at the back of the curtain being kept at the standard voltage. The Committee on Automobile Headlamps of this Society has made a comprehensive report which will be found in the *TRANSACTIONS*.⁶⁹

Mounted on the roof of a limousine type of automobile in such a way that it can be raised or lowered, or rotated 2 ft. (60 cm.) above the roof of the car by the chauffeur, a signal light is made up⁷⁰ of a lamp and combination of colored glasses. By this means the car can be readily located by its owner when it is in the midst of a crowded group of other cars. Many times in backing down narrow roads or into garages, it would be helpful to have a light in the rear of the machine. This need has been provided for⁷¹ in a combination searchlight and tail light contained in a compact case, the two parts being independently controlled.

An improved micrometer focussing device permits⁷² of the most delicate adjustment of the lamp in an electric headlight of a locomotive. Independent movement vertically, horizontally and laterally is provided. In a new headlight designed for use on mine locomotives the lamp is fastened to the reflector and the latter and the lamp socket are flexibly suspended⁷³ in the casing. This helps in avoiding the effects of vibrations and jars. Another large railroad⁷⁴ has started to replace kerosene lamps with electrical lamps for locomotive headlights. About 2,500 will be changed at the rate of from 75 to 100 per month.

Signal Lamps.—Special lamps for signalling and for lighting equipment have been developed⁷⁵ for use on aeroplanes. A telegraphic signal lamp has been devised⁷⁶ consisting of a brass anchor light with Fresnel lens and a specially constructed Morse key which is provided with a condenser placed in its supporting base. Many devices have been worked out⁷⁷ to warn users of

⁶⁹ *TRANS. I. E. S. (U. S.)*, July 20, 1918, p. 259.

⁷⁰ *Elec. Record*, Jan., 1918, p. 43.

⁷¹ *Elec. Record*, June, 1918, p. 37.

⁷² *Pop. Sci. Monthly*, April, 1918, p. 579.

⁷³ *Elec. Record*, July, 1918, p. 33.

⁷⁴ *Elec. Rev. (U. S.)*, Aug. 18, 1917, p. 283.

⁷⁵ *Elec. Wld.*, May 18, 1918, p. 1031.

⁷⁶ *Elec. Merchandising*, May, 1918, p. 275.

⁷⁷ *Elec. Wld.*, Oct. 6, 1917, p. 696.

heating devices such as irons, etc., that the current is on. To meet this need a line of receptacles and flush plates has been designed. A standard flush plate is used in which is set a small bull's-eye of ruby glass. Behind the bull's-eye is a receptacle equipped with a two-candlepower lamp which shines through the glass as long as the current is turned on.

Motion Picture Projection.—After considerable experimentation the past year has seen the introduction of the gas-filled tungsten lamp into the realm of motion picture projection. Owing to the fact that the intrinsic brilliancy of a tungsten filament at operating temperatures is only about one-fourth that of the crater of the arc ordinarily used and that the ordinary condensers pick up a very large percentage of the useful flux of the arc and would take up only a very small percentage of that from the filament it was thought that the use of a tungsten lamp was impracticable in cinematography.⁷⁸ These difficulties have been met by the use of a specially designed optical system. The most important part of this system is a condensor which is designed with corrugations like a semaphore or lighthouse lens. It was found possible with this condensor ($2\frac{1}{2}$ by $6\frac{1}{2}$ ft. (75 by 200 cm.) conjugate foci) to intercept light through a solid angle of 75° instead of 32° available with the ordinary plano condensers. The corrugations also performed the further function of breaking up the image of the filament thus eliminating streaks and non-uniform illumination on the screen. A further gain in the effective light available was obtained by using a spherical mirror back of the filament, so adjusted that the image of the filament is thrown back on itself in such a way that the images of the segments occupy the space between the segments and thus produce the effect of a solid band of light. The lamp is of the gas-filled type having a specially coiled filament, the coils in four segments lying in one plane. Two sizes are at present available, one of 600-watts capacity, taking 20 amperes at 30 volts, the other of 750-watts capacity, taking 30 amperes at 20 volts. Extreme precautions are necessary with these lamps to keep the current at a constant value since the filament operates normally at a very high temperature which does not allow of much fluctuation if the rated life of 100 hours is to

⁷⁸ *Gen. Elec. Rev.*, Dec., 1917, p. 979.

See also *TRANS. I. E. S.*, June 10, 1918, p. 232.

be obtained. These lamps are said to be suitable for use in theatres projecting pictures up to 14 ft. (4.3 m.) wide and with a throw as far as 80 or 90 ft. (24 or 27 m.).

It is claimed⁷⁹ that in Germany it has been found possible to make lamps for projection purposes using currents as high as 200 amperes. The difficulty in making air-tight joints where the leading-in wires pass through the stem is said to have been overcome by a special method which, however, is not disclosed. Apparently the lamps are of the same type, using a mirror, as those just described. The efficiency is given as in the neighborhood of 0.25 watts per hefner candle.

Miners' Lamps.—The U. S. Bureau of Mines has published⁸⁰ a pamphlet in which has been compiled the coal mine fatalities in the United States. There is included a list of permissible explosive motors, and lamps, bulbs, glasses, igniters, etc. This supercedes all previous lists dealing with safety lamps of both the electric and flame type. In England⁸¹ several types of flame safety lamps as well as some electric lamps have been approved during the past year. In the annual report of the Chief Inspector of Mines of Great Britain for 1916⁸² it is stated that difficulty is still experienced in getting British manufacturers of glassware to produce safety-lamp glasses capable of passing the necessary tests and conforming to the general requirements as to color, shape and uniformity.

INFLUENCE OF THE WAR.

While on the battlefield light, in all its various applications, continues to be a vital factor, as in signalling through the use of colored flares, rockets, etc.; in specific illumination as of "No Man's Land" to prevent surprises; in searchlights both to aid in advances and to protect from attacks; in flash lamps for trench and scouting work; and while in the factory there has been a greatly increased use of light, the influence of the war on ordinary domestic lighting is strongly in the direction of curtailment for the purpose of saving fuel.

The high speed night and day work required in munition plants

⁷⁹ *Elec.*, April 12, 1918, p. 846.

⁸⁰ *Elec. Rev.* (U. S.), Jan. 19, 1918, p. 137.

⁸¹ *Elec. Rev.* (Lond.), March 22, 1918, p. 274.

⁸² *Elec.* (Lond.), Jan. 18, 1918, p. 590.

and those working on war orders has emphasized⁸³ the importance of good lighting. Lack of proper illumination results in accidents, mistakes, waste and labor limitations. In a powder mill the question of safety is of paramount importance and special precautions are taken in such places to enclose the units to avoid possible explosion resulting from exposed heated filaments, or arcs, in case of bulb breakage. Another aspect of wartime lighting is to be found in the lighting of the cantonments which sprang up like magic last fall. Here the provision of sufficient illumination to insure cheerfulness had to be combined with adequate shielding to protect the eyes of the men from glare from the lamps. The problem of protective lighting of buildings and roads also required careful consideration.

It is stated⁸⁴ that in both the French and Italian armies portable electric light plants are being largely made use of for the lighting of staff quarters. The generator, coupled direct to a gasoline engine and mounted on a wooden platform is capable of being carried by a couple of soldiers, and, having been transported on a motor truck can be utilized in about an hour's time after its arrival.

Restricted Lighting.—The Government has followed the lead of foreign countries in endeavoring to save fuel by issuing orders restricting its use for the purpose of maintaining display lighting of all kinds. The first action taken, November 15, 1917, was the restriction of the use of coal for sign lighting to the hours between 7.45 p. m. and 11 p. m. with certain exceptions.⁸⁵ Experts of the Fuel Administration estimated that 250,000 tons of coal are used each year for display electric lighting and it was hoped much of this could be saved for other uses.

Subsequently⁸⁶ there was under consideration by the Fuel Administration a plan for "lightless nights" in which it was proposed to darken all outdoor lighting other than that required for police purposes. This plan was put into effect by an order issued December 14th making Sunday and Thursday nights practically "lightless." This order also provided for the restriction of considerable indoor lighting. Both orders were made inopera-

⁸³ *Elec. Rev.* (U. S.), Jan. 5, 1918, p. 3.

⁸⁴ *Elec. Rev.* (Lond.), Oct. 12, 1917, p. 356.

⁸⁵ *Elec. Wld.*, Nov. 17, 1917, p. 969.

⁸⁶ *Ibid.*, Dec. 15, 1917, p. 1159.

tive⁸⁷ for districts where energy is obtained through water power. January 2nd a still more drastic order⁸⁸ by the State Federal Fuel Administrator made the lightless rules apply to every night but Saturday in New York State. However, these orders were suspended⁸⁹ April 25th and a new order which is more drastic for the New England and Eastern States than in those states where the fuel transportation problem is not so great, went into effect July 24th.⁹⁰ Under this order the use of light generated or produced by the use of coal, gas, oil or other fuel for illuminated or display advertisements, announcements or signs or for external ornamentation of any building is to be discontinued on the first four days of each week in the eastern states and the first two days throughout the remainder of the United States. Street illumination is restricted and the use of light in show windows prohibited from sunrise to sunset of each day of the lightless nights designated in the order. Similar curtailments were made in Michigan;⁹¹ St. Louis, Mo.; Indianapolis, Ind.; Minneapolis, Minn.; Cincinnati, Ohio, and throughout New England. In Philadelphia⁹² gas lighters have been ordered not to light the gas lamps until darkness, as a fuel conservation aid. Previously they had often been lighted as early as 3 p. m. New York City experimented⁹³ with partly darkened streets on the night of June 4th as a precaution against possible bombing by aircraft sent out from German submarines.

The president of one of the largest light and power companies in the country⁹⁴ is quoted as having given the following as the advantage of restricted lighting: "From my viewpoint the most important effect of the curtailment in the hours of operation of electrically lighted signs will be the advertising effect, as the absence of extreme illumination from signs and other special lighting will bring home to people the fact that economy and conservation of resources are policies to be followed by everybody, let each particular saving be ever so small."

⁸⁷ *Elec. Rev.* (U. S.), Jan. 5, 1918, p. 32.

⁸⁸ *Elec. Wld.*, Jan. 5, 1918, p. 58.

⁸⁹ *Elec. Wld.*, April 27, 1918, p. 888.

⁹⁰ *Elec. Wld.*, July 6, 1918, p. 26, and July 27, 1918, p. 176.

⁹¹ *Signs of the Times*, Feb., 1918, p. 18.

⁹² *Gas Age*, Jan. 15, 1918, p. 93.

⁹³ *Elec. Wld.*, June 8, 1918, p. 1221.

⁹⁴ *Central Station*, Jan., 1918, p. 164.

One of the results of the restricted sign-lighting orders⁹⁵ has been to call attention to the relation which such lighting has to the general illumination of streets and to emphasize the possibility of increasing the regular street-lighting equipment in those localities where a large amount of display lighting has led the public to become accustomed to a certain degree of illumination. The necessity of cutting down all kinds of display and sign lighting in order to save fuel has raised a large amount of discussion in which a question as to the advantage gained has been steadily growing.⁹⁶ In Boston it is claimed that with about 3,300 signs in use only about 0.7 per cent. of the illuminating company's annual coal consumption is involved. One of the corporations operating in a number of cities in and out of New England states that the total fuel requirement of the signs in its service is less than 300 tons (270 metric tons) in a year. In general there was a feeling toward the end of last year among New England central stations that the advantage gained in fuel saving through curtailment of signs is very doubtful, and a similar feeling prevails regarding street lighting. Reports from various cities indicate⁹⁷ a belief that the saving in coal from such restrictions is not comparable with the deleterious effects. In Boston approximately one-third of the gas lamps and one-fifth of the magnetite arc lamps were cut out and a good deal of complaint was made. At Cambridge, Worcester and Salem service was curtailed but subsequently restored. However, there has been shown throughout the country a marked willingness to comply with any requests made by the government in this direction. A decided protest against the whole idea of restricted lighting for fuel saving purposes is found in a paper before the New York Section of this Society where it is emphasized that attention to waste in other directions will be enormously more effective than any possible results from restricted lighting.

In England the first order under the new Defense of the Realm Regulations⁹⁸ which impowers the Minister of Munitions to restrict the use of any form of artificial light was applied to the county borough of Derby. It was decreed that no light should be

⁹⁵ *Elec. Wld.*, Dec. 8, 1917, p. 1087.

⁹⁶ *Elec. Wld.*, Oct. 27, 1918, p. 825.

Ibid., April 6, 1918, p. 709.

⁹⁷ *Elec. Wld.*, March 9, 1918, p. 526.

⁹⁸ *Elec. Rev. (Lond.)*, Jan. 11, 1918, p. 41.

used in any shop front on any week-day other than Saturday after 3.30 p. m. Certain exceptions are permitted the object of the restrictions being maintenance of supply of power. Further restrictions in the consumption of gas and electricity for lighting purposes were ordered⁹⁹ in London on March 26th. Consumers were allowed for any quarter, only five-sixths of their consumption for the corresponding quarter for 1916 or 1917. And a paradoxical situation has been created by compelling the gas and electrical supply companies to report those using more than their allowed quantity.

The lighting conditions in many provincial towns in England¹⁰⁰ have been so unsatisfactory owing to the war restrictions that a general awakening on the subject seems to have taken place and where it has seemed feasible the lighting has been increased. On the other hand numerous towns¹⁰¹ report a complete or almost complete cessation of street lighting during the summer. A new order rationing both light and fuel went into effect in England on July 1st.¹⁰² In Scotland¹⁰³ the restrictions regarding shop lighting and street lighting have been modified. But drastic reduction¹⁰⁴ amounting to about 50 per cent. has been arranged for in Glasgow. Lighting is to be graduated in accord with traffic requirements. Owing to the curtailment of Irish coal supplies by about 25 per cent. lighting restrictions on a somewhat drastic scale have been put in force in all cities and towns in Ireland.¹⁰⁵

The municipal authorities at Rome have issued¹⁰⁶ a new set of regulations controlling the use of electricity for lighting. Exits of theatres, concert halls, etc., will be allowed only one lamp not exceeding 60 watts. The present lighting of shop windows and show cases is to be reduced 50 per cent. by discontinuing one-half of the lamps in use and keeping the candlepower of the remainder at the present value. In Berlin¹⁰⁷ the authorities have published a statement "that the dearth of coal makes it indispensable to stop lighting the steps of halls." It would seem to be very question-

⁹⁹ *Illum. Engr.* (Lond.) March, 1918, pp. 67 and 92.

¹⁰⁰ *Illum. Eng.*, Nov., 1917, p. 296.

¹⁰¹ *Elec. Rev.* (Lond.), April 19, 1918, p. 372.

¹⁰² *Gas Jour.*, June 11, 1918, p. 468.

¹⁰³ *Gas Jour.*, Nov. 20, 1917, p. 381.

¹⁰⁴ *Elec. Rev.* (Lond.) May 3, 1918, p. 421.

¹⁰⁵ *Gas Jour.*, April 2, 1918, p. 28.

¹⁰⁶ *Elec. Rev.* (Lond.), Jan. 4, 1918, p. 10, and March 15, 1918, p. 252.

¹⁰⁷ *Illum. Eng.* (Lond.), Sept., 1917, p. 242.

able whether the saving in coal would compensate for the accidents which such procedure would involve. Denmark also is confronted with the possibility of a return to primitive methods of lighting and heating. A report from a war correspondent from Petrograd¹⁰⁸ states that on January 11th the electric light failed in many parts of the city and on the 12th a candle cost $2\frac{1}{2}$ rubles or \$1.25.

Supplies.—In England¹⁰⁹ the Minister of Munitions has taken possession of all calcium carbides in the United Kingdom except the stock of those persons not owning more than 50 pounds (23 kg.). A permit is required to buy or sell this material. In Sweden a similar action became necessary owing to a shortage created by the scarcity of petroleum. In Holland a rationing of the coal gas supply for cooking and lighting has been decided upon.

Following the example of Great Britain¹¹⁰ the Signal Corps of the government has requested the loan of lenses for cameras for the fleet of observation aeroplanes now under construction. A request has also been made¹¹¹ for all binoculars and telescopes and up to November 23rd of last year over 600 had been turned in. The Bureau of Standards is now perfecting¹¹² a substitute for the German "crown barium" glass used in lenses and will later be able to meet all needs. Hundreds, however, are required at once. England is now making lenses better than those formerly imported from Germany, but is utilizing all produced.

Camouflage.—It has been pointed out¹¹³ that by the use of properly colored glasses in conjunction with binoculars and monoculars it may be possible to defeat the camouflaging effect of colors of uniforms or objects of any kind so that the latter will appear in contrast to their surroundings. Various methods of "camouflage" have been worked out¹¹⁴ for the concealment of hangars, houses and mercantile shipping based on color combination. Most of these do not seem to have been very successful. What appears to be a promising method is based on what is sometimes called Thayer's Law of the invisibility of an object

¹⁰⁸ *Elec. Times*, Jan. 17, 1918, p. 40.

¹⁰⁹ *Gas Jour.*, Oct. 2, 1917, pp. 17 and 37.

¹¹⁰ *Elec. Wld.*, Oct. 27, 1917, p. 832.

¹¹¹ *Sci. Amer.*, Jan. 19, 1918, p. 67.

¹¹² *Photographic Jour. of Amer.*, Nov., 1917, p. 485.

¹¹³ *Elec. Wld.*, Sept. 29, 1917, p. 638.

¹¹⁴ *Elec.*, Feb. 1, 1918, p. 627.

shaded darker on its upper parts and painted lighter on its lower or under sides. Attention has been called to the fact that in work of this kind it is desirable to deceive the camera as well as the eye.

STREET LIGHTING.

Since the introduction of the high-powered, gas-filled tungsten lamp into the field of street lighting, a great many arc lamps have been displaced by them. But that the arc lamp is by no means a back number in this sphere of work is demonstrated by its use in the so-called intensive or ornamental street lighting in the main business streets of large cities.¹¹⁵ This type of lighting embodying the "city beautiful" plan was initiated in the so-called "Path of Gold" on Market street in San Francisco, and a similar installation was made at about the same time in Salt Lake City. In last year's report reference was made to plans for the use of this system in the Triangle district of San Francisco and Los Angeles, the latter city introducing the novelty of having two designs of standards alternating with somewhat different silhouettes. Among the other cities in which the pendant type luminous arcs have been installed during the past year may be mentioned Philadelphia, Pa.; Baltimore, Md.; Bridgeport and New Haven, Conn.; Lowell, Cambridge and Salem, Mass., as well as others to be referred to later.

The Bureau of Standards has begun work on an extensive series of measurements¹¹⁶ designed to provide information to be incorporated in a street-lighting circular to be issued by the Bureau. Among the early features of the work were measurements made on two types of street arc lamps to determine the distribution of light and variation of candlepower and efficiency with current.

Some statistics on street lighting will be found under the caption "Other Exterior Illumination: Parkways," and under the heading of "War: Restricted Lighting" will be found references to street-lighting conditions in various cities, while information on progress elsewhere in this direction throughout the country may be gleaned from the following illustrations:

San Francisco, Cal.—In the high class retail shopping district

¹¹⁵ From data submitted to the Committee on Lighting and Illumination of the American Institute of Electrical Engineers, and used by permission.

¹¹⁶ *Elec. Eng.*, Dec., 1917, p. 36.

adjacent to Market street there is proceeding the installation of fixtures which will enable an extension of the luminous arc system, using two 6.6 ampere lamps on special high standards. These lamps were to have gone into service during the year but owing to war conditions it is doubtful if they will be lighted until after the war. These fixtures will replace a large number of 210-watt, five-globe electroliers. The Twin Peaks Tunnel approximately 12,000 ft. (3.7 km.) long, has been lighted by the city authorities by 25-watt lamps placed in refuge niches, spaced at intervals of 50 ft. (15 m.) on each side. Being recessed these lamps while giving sufficient illumination, do not shine into the eyes of the motormen.

During the year arc lamps for street lighting have decreased from 1,946 to 926, while a corresponding increase has occurred in the number of gas-filled tungsten lamps with refractors. Owing to the shortage of power in California, it will be necessary for the street lighting to be cut down and the same cause will affect all types of ornamental and sign lighting.

Seattle, Wash.—Since April all cluster lamps in the downtown district¹¹⁷ with the exception of four at each corner of street intersections have been eliminated. If the experiment proves feasible it will be continued, the purpose being the conservation of oil. No changes have been made in the residential districts.

Portland, Ore.—New street lamps have been installed only in those locations where they would directly or indirectly assist war activities. A recommendation for 1,000 new units was set aside by the City Council.

Lincoln, Neb.—Carbon arc lamps have been replaced¹¹⁸ by double the number of incandescent lamps of the 600 cp., gas-filled tungsten type.

West Liberty, Ind.—Unusual evidence of appreciation of the value of good street lighting is presented¹¹⁹ in the case of this small city which has a population of only 1,700. Originally lighted by 26 arc lamps with one lamp at each street intersection, a change was decided on when street paving was under consideration. As a result the old system was dismantled, and ornamental posts to the number of 24 for the business district and 178 for

¹¹⁷ *Elec. Wld.*, April 13, 1918, p. 807.

¹¹⁸ *Municipal Jour.*, April 6, 1918, p. 281.

¹¹⁹ *Elec. Wld.*, Dec. 15, 1917, p. 1141.

the residential district, using 100-watt tungsten units on the former and 100 cp. units for the latter, have been provided.

Kansas City, Mo.—600 gas lights have been replaced with electric lights.¹²⁰

St. Louis, Mo.—On account of the war the increase in the number of lamps for street, alley, and park lighting has been exceptionally small and probably not more than 20 per cent. of what it would have been in a normal year. Only approximately 177 incandescent gas lamps, 7 arc lamps, and 3 incandescent lamps have been placed in service. At the request of the Government authorities early in the year, about 7 per cent. of incandescent gas lamps and 5 per cent. of arc lamps were discontinued for a term averaging four months. The red globes of what are termed "traffic lamps" have been changed to designation globes (white globes with red horizontal bands).

Pine Bluff, Ark.—A new system has been installed¹²¹ comprising 106 ornamental posts in place of 56 in the business district furnished with one 250 cp. lamp each. 473 incandescent lamps in the residential district have been increased from 32 to 60 cp. each.

New Orleans, La.—The first installment of twenty miles (32.18 km.) provided for and referred to in last year's Report has been completed.¹²² It consists of ornamental standards mounting 200 cp. series tungsten lamps in round white globes in double rows spaced about six units to the block. 3,300 pendant type luminous arcs have been installed.

Grand Rapids, Mich.—It has been decided¹²³ to replace arc lamps with incandescents of the gas-filled type and in sizes from 400- to 600-watts. About 1,500 lamps are involved.

Detroit, Mich.—Practically all extensions of street lighting have been in outlying sections of the city only, in sections recently annexed and where no street lighting had been provided before annexation. For this purpose about 500 lamps of the 4 amperes arc type were installed. More than 1,000 arc lamps have been disconnected in an endeavor to economize in the consumption of fuel. During the winter additional lamps in the residential sections were cut out but subsequently placed in operation again.

¹²⁰ *Elec. Rev.* (U. S.), May 11, 1918, p. 818.

¹²¹ *Municipal Jour.*, Oct. 18, 1917, p. 387.

¹²² *Elec. Wld.*, Feb. 9, 1918, p. 297.

¹²³ *Elec. Rev.* (U. S.), Dec. 8, 1917, p. 982.

360 of the 4 ampere luminous arcs have been purchased for installation in residential sections for the ensuing year.

Columbus, Ohio.—All arc lamps except those of magnetite type are to be replaced with gas-filled tungsten lamps of the 400 cp. size. 700 additional lamps of the latter type are to be installed.¹²⁴ Late last year as a fuel conservation measure the mayor ordered¹²⁵ that only the top lamp in clusters of street lamps in the business district be used.

Buffalo, N. Y.—The installation of approximately 2,000 street-lamp posts of the boulevard or ornamental type equipped with mantle gas-lamp heads has been provided for.¹²⁶ The lamps will range from 60 to 150 cp. Provision has also been made for posts equipped for 40 cp. incandescent mantle lamps using naphtha or hydro-carbon fuel. These posts are to be of the boulevard type.

Savannah, Ga.—Plans have been submitted¹²⁷ to the city council by an illuminating engineer for an entire street lighting system. It is proposed to replace arc lamps with gas-filled tungsten lamps, and substitute single lamp posts for those carrying ornamental cluster lamps.

St. Petersburg, Fla.—Gas street lighting has been discontinued.¹²⁸

Boston, Mass.—The number of street lamps in the city of Boston up to and including July 1, 1918 is given in the following table:

Magnetite arc lamps, 800 cp.....	5,023	Total 5,265
White Way Boulevard type.....	242	
<hr/>		
Incandescent—40 cp.	3,283	
60 cp.	1,278	
80 cp.	11	
100 cp.	10	
320 cp.	6	
Gas lamps—60 cp. single mantle.....	9,663	
100 cp. double mantle.....	70	
F. A. open flame.....	144	

¹²⁴ *Elec. Wld.*, March 30, 1918, p. 702.

¹²⁵ *Elec. Wld.*, Dec. 29, 1917, p. 1265.

¹²⁶ *Municipal Jour.*, March 30, 1918, p. 267.

¹²⁷ *Elec. Wld.*, Feb. 9, 1918, p. 338.

¹²⁸ *Gas Age*, Feb. 1, 1918, p. 144.

During the past year there have been added for decorative purposes about 100 lamps of the White Way Boulevard type which number is included in the above table.

Gardner, Mass.—93 gas lamps are to be replaced with electric lamps and 750 new electric lamps are to be installed.¹²⁹

The installation of a system of street lighting, the replacement of one type by another, increases or other changes in existing installations have been planned or provided for in the following cities:¹³⁰ Hoquiam, Prosser, and Spokane, Wash.; Orange, Cal.; Mannville, Wyo.; Nampa, Idaho; Chester, Livingston and Harlem, Mont.; Omaha, Bayard, Oconto, Carroll and Hartwell, Neb.; Lanesboro, Eddyville, Vail and Hamburg, Ia.; Eldorado, Randolph and Palco, Kas.; Columbus and Corydon, Ind.; Toledo and Dayton, Ohio; Knoxville, Tenn.; Netcong, Hopewell, Perth Amboy, Newton and Jersey City, N. J.; Reidsville, Ga.; Halifax, Greensburg and Beaver Falls, Pa.; Dunkirk, Tully and Johnston, N. Y.; Terryville, Conn.; Whitman and Fall River, Mass.; Grayville, Ill.; Fort Smith, Ark.; Gueydan, La., and St. Thomas, Ont.

England.—Owing to complaints¹³¹ that the illumination provided under war regulations was less than in other districts, the Metropolitan Borough of Islington has had a survey made, by an illuminating engineer, of lighting conditions, and recommendations for improvements have been made. The London "Safety First" Council has resolved¹³² to invite the Central Lighting Authority through the Home Secretary, to adopt a diffused, substantially uniform illumination of districts in the Greater London area where military exigencies and local conditions permit. At Denzes a special committee has been appointed¹³³ to consider the question of lighting the town by electricity after the war. At Tottenham it has been decided to replace arc lamps with incandescents and the Stepney Borough Council has recommended¹³⁴ a disposal of its stock of arc lamps and fittings owing to the increased use of tungsten gas-filled lamps.

Petrograd.—Reports from Petrograd¹³⁵ indicate great un-

¹²⁹ *Elec. Wld.*, June 29, 1918, p. 1401.

¹³⁰ Construction Notes, *Elec. Wld.*, *Elec. Rev. and Jour. of Elec.*, 1917-18.

¹³¹ *Elec.*, Feb. 15, 1918, p. 690.

¹³² *Elec. Rev.* (Lond.), April 26, 1918, p. 398.

¹³³ *Ibid.*, Feb. 22, 1918, p. 180.

¹³⁴ *Gas Jour.*, Feb. 19, 1918, p. 340.

¹³⁵ *Elec. Times*, April 25, 1918, p. 256.

certainty in the lighting situation. One correspondent writes "For indoor illumination you use a candle and it costs you five shillings. The lighting has been bad for two years."

South Africa.—A report of the number and candlepower of street lamps in various cities of South Africa has been published.¹³⁶ The Paarl (Cape Province) municipality is planning on an extension of the street lighting system.

OTHER EXTERIOR ILLUMINATION.

Data have been given¹³⁷ showing the lighthouse equipment of Great Barrier reef which forms a natural breakwater about 1,000 miles (1600 km.) long on the eastern coast of Queensland. Flashlight acetylene lamps are used of the automatic or "unattended" type, those of 1,500 cp. being visible for 13 miles (21 km.) while those of 5,000 cp. can be seen at nearly 26 miles (42 km.). What is said to be the most complete and modern wholesale produce market in the country,¹³⁸ has been completed in Los Angeles, Cal. The lighting is accomplished by means of 36 gas-filled lamps of 300 cp. each, supported at a height of approximately 30 ft. (9 m.) by tubular steel posts 5 in. (13 cm.) in diameter and tapering toward the top, which is arranged as a flag-staff.

Display Lighting.—A good illustration of co-operation between a landscape architect and an illuminating engineer is to be found in the lighting of a fountain on a country estate.¹³⁹ By the use of concealed lighting (red, green and blue lamps in four sets of outlets), the water in the pool and falls is made to assume the primary hues and intermediate tints. The circuits are arranged for independent or flasher control. The use of color in floodlighting and display lighting¹⁴⁰ was well illustrated in the spectacular illumination of the Canadian National Exhibition at Toronto. The fountain was lighted by 16 groups of floodlighting units, nine 200-watt lamps to a group arranged around the outer rim of the large catch basin just below the surface of the water. White, blue and green lamps were employed. The dome of the horticultural building was lighted by alternate rows of red, white

¹³⁶ *Elec. Rev.* (Lond.), Oct. 12, 1917, p. 357.

¹³⁷ *Elec.*, April 12, 1918, p. 846.

¹³⁸ *Elec. Rev.* (U. S.), June 8, 1918, p. 962.

¹³⁹ *Elec. Rev.* (U. S.), March 30, 1918, p. 551.

¹⁴⁰ *Elec. News*, Oct. 1, 1917, p. 56.

and blue lamps, 212 in all. The grandstand was provided with 40 reflector units of which 24 were stationary and the remainder movable. The reflectors were 28 in. (71 cm.) in diameter, carried 1,000-watt lamps and were provided with colored glass screens.

Parkways.—Statistics have been gathered¹⁴¹ by the Bureau of Census showing the relative use of different illuminants for park and street lighting during the past ten years. The results are shown in the following table:

Type of lamp	Per cent. of total number		
	Park lighting	Street lighting	
	1916	1909	1907
Electric arc	8.5	34.5	34.2
Incandescent electric	80.1	16.3	10.6
Gas	6.2	41.5	45.1
All other	5.3	7.7	10.1

It will be seen that for this type of lighting the use of incandescent lamps has been growing steadily. The fact that at the 153 safety islands at street intersections in Chicago,¹⁴² 270 accidents occurred in one year has led to investigation of causes and a recommended type of standard. Posts should be painted white and surmounted by a red globe. A white globe with a red bulb inside has not proved satisfactory, nor the two-colored globe, red above and white below to light up the posts. Small white lights in opaque reflectors just below the red signal will furnish the illumination of the post without causing glare in the eyes of drivers.

The use of small farm-lighting plants¹⁴³ operating on a storage battery is growing.

Floodlighting.—A novel method of obtaining the floodlighting of a store building front was worked out¹⁴⁴ in a city where the projection of floodlight across the street is prohibited. An electric sign extending the length of the building was made in the form of a valance and attached to the outer edge of the eaves of the roof. The lower outline of the valance is closely studded with bull's-eyes which project light used for floodlighting in the rear of the sign; 100-watt gas-filled lamps are used as sources. More attention is being paid to detail in floodlighting installa-

¹⁴¹ *Elec. Wld.*, Sept. 29, 1917, p. 638.

¹⁴² *Municipal Jour.*, March 16, 1918, p. 221.

¹⁴³ *Elec. Rev.* (U. S.), Dec. 22, 1917, p. 1078.

¹⁴⁴ *The Dougherty News*, July, 1918, p. 8.

tions.¹⁴⁵ This is illustrated in the case of a Western bank lighted by the use of 12 projectors containing six 500-watt and six 750-watt lamps. It was desired to preserve the appearance of the architectural features as seen under noon sunlight, and projectors placed in three horizontal banks were mounted on a building diagonally opposite in such a position and at such a height as to simulate this condition. Another example¹⁴⁶ of floodlighting a large building is that of the administration offices of the Utah University which is rather unique as educational institutions are not ordinarily so treated. Ten 500-watt projector units are used. The floodlighting of the traffic officer¹⁴⁷ as he stands at his post on dark and foggy nights has been found so satisfactory in St. Louis that searchlights for this purpose have been installed at five especially dangerous crossings.

A unique application of floodlighting¹⁴⁸ is to be found in its use to illuminate an enormous sign made of concrete and built into the side of a hill. One of the numerals in the sign is 70 ft. by 130 ft. (21 m. by 40 m.). Nine 1,000-watt projector units are used, arranged in a horizontal line on a platform supported by two poles.

Protective Lighting.—Much attention and study has been given to the subject of protective lighting¹⁴⁹ as many factors of illuminating engineering practice such as intensity, distribution and glare have marked significance and their correct co-ordination is of vital importance in the application of this branch of lighting to industrial activities. It has been pointed out that searchlamp and flood-lamp requirements are different and that in many instances either or both are used when ordinary reflectors would be sufficient.

War conditions and the enormous amount of capital involved¹⁵⁰ has led a number of oil companies in Oklahoma to protect their properties at night by floodlighting. Owing to the areas to be covered, in one case a farm 14 miles (23 km.) by 3 to 4 miles (5 to 6 km.), special equipment was devised. The lamps are mounted 56 ft. (17 m.) from the ground on pipes extending up

¹⁴⁵ *Jour. of Elec.*, Jan. 1, 1918, p. 37.

¹⁴⁶ *Jour. of Elec.*, March 15, 1918, p. 294.

¹⁴⁷ *Municipal Jour.*, March 5, 1918, p. 12.

¹⁴⁸ *Elec. Wld.*, Sept. 29, 1917, p. 635.

¹⁴⁹ *Elec. Wld.*, June 15, 1918, p. 1269.

¹⁵⁰ *Gen. Elec. Rev.*, Oct., 1917, p. 516.

from the roofs of look-out towers. These towers are located approximately 1 mile (1.6 km.) apart and an armed guard at each one controls the lamp which may be moved both horizontally or vertically, thus sweeping the beam over a large area. The units used are floodlighting projectors containing 400-watt lamps. To aid in constantly guarding a western dam¹⁵¹ use has been made of a source consisting of a 14-in. (35.5 cm.) silvered reflector backing a group of ordinary gas mantles. The projector is mounted above an oblong case containing the fuel and pressure tanks and all operating valves. Gasoline is used for fuel and it is claimed the arrangement is easily handled by one man and particularly useful for isolated locations where gas or electricity is not available. As war conditions continue¹⁵² the importance of protective lighting has been more and more appreciated. This is particularly true of power plants and various methods are employed. A system used by a large plant which supplies power to a lead and zinc mining district leaves the power-house itself in total darkness but all avenues of approach so brilliantly lighted that the unnoticed advent of a nocturnal visitor would be impossible.

The United States War Department has issued a pamphlet on "Protective Lighting" (Document No. 800) in which the need for protection of public works, industrial plants and other property which is vital to the prosecution of the war and to the welfare of the public is described. The important place of artificial lighting as a means of guarding such property and methods of making such lighting effective and of insuring continuity of lighting service are described. The material for this pamphlet was prepared by our Committee on War Service.

Sports.—The lighting of outdoor playgrounds is by no means confined to electric sources.¹⁵³ Gas arcs have been used and those of the five-mantle outdoor type have been found satisfactory. In general, use of floodlighting for outdoor sports has become so common¹⁵⁴ that it is something of a novelty to find a place where this method has not been used. In the case of a certain athletic field the cost precluded the adoption of floodlighting. Good results were obtained, however, by using thirteen 1,000-watt lamps

¹⁵¹ *Pop. Mech.*, Dec., 1917, p. 894.

¹⁵² *Jour. of Elec.*, Dec. 15, 1917, p. 540.

¹⁵³ *Gas Industry*, Sept., 1917, p. 462.

¹⁵⁴ *Elec. Wld.*, Dec. 22, 1917, p. 1200.

in angle reflectors on each side of the field which is approximately 450 ft. long by 270 ft. wide (137 m. by 82 m.). On one side the lamps were mounted under the edge of the roof of the grand stand. On the other side they were supported on a cable carried by three poles. The lamps were all mounted at approximately 45 ft. (14 m.) from the ground and spaced about 25 ft. (7.6 m.) apart. The average illumination was 1.55 foot-candles (1.68 mph.)* with a maximum of 4.40 (4.74 mph.) and a minimum of 0.394 (4.24 mph.). In front of the grand stand the average illumination was 2.79 foot-candles (3.0 mph.). Trap shooting by electric light¹⁵⁵ has become quite popular, arrangements for it having been installed among other places, in Salem, N. J.; Jacksonville, Ill.; Chicago and Evanston, Ill.; Yorklyn, Del.; Newark, Cal.; Clarksville, Ia.; and Portland, Ore.

A case is recorded¹⁵⁶ of threshing being carried on at night with the aid of lamps placed in the barn. A shortage of labor having made it impossible to get help by day, enough men who are employed in shops in the daytime were obtained to carry on the work.

Electrical companies and town councils have offered¹⁵⁷ to provide the lighthouses necessary to light the aerial route between Dayton, Ohio, Indianapolis, Ind., and other cities to be used by the aviation corps of the army. Searchlights will be turned upward each night to guide the aviators in their flights.

INTERIOR ILLUMINATION.

Types.—Certain conclusions were reached regarding the relative expense of direct, indirect and semi-indirect methods of illumination in connection with a series of tests by a foreign engineer to determine the relative costs and merits of gas-filled tungsten incandescent lamps and arc lamps.¹⁵⁸ The tests were made in a room ten meters by six meters, with white ceiling and frieze and gray walls. The watts per lux per square meter of floor area was taken as a basis of comparison. The results indicated that semi-indirect lighting with tungsten lamps is as cheap

¹⁵⁵ *Jour. of Elec.*, Dec. 15, 1917, p. 558.

¹⁵⁶ *Elec. Wld.*, Dec. 1, 1917, p. 1072.

¹⁵⁷ *Elec. (Lond.)*, Nov. 23, 1917, p. 260.

¹⁵⁸ *Zeits. Ver. Deutsch. Ing.*, July 28, 1917, p. 625.

See also *Science Abstracts B*, Oct. 31, 1917, p. 392.

* Milliphot — (1 phot = 1 lumen incident per sq. centimeter = 10,000 lux = 1,000 milliphot.)

as, or cheaper than, direct lighting; for equal illumination indirect lighting is about 20 per cent. dearer than direct and 30 per cent. dearer than semi-indirect lighting. These results have been criticized by another foreign engineer who claims that indirect is $82\frac{1}{2}$ per cent. and semi-indirect 40 per cent. dearer than direct lighting where the comparison is made with the most efficient types of reflectors in the three systems, given identical conditions, and as a requirement, the same foot-candle illumination. Reference should be made to the data presented¹⁵⁹ to this Society on the proportions for general and localized lighting. A large number of cases where such a combination is used makes any data on the subject valuable.

House Lighting.—For some time there has been a tendency in the better class of new houses to omit the center chandelier, but a western builder has carried this idea still further and eliminated side lighting brackets, thus causing no breaks in the lines of either walls or ceilings.¹⁶⁰ Plenty of daylight is furnished and at night the same effect is simulated through the use of portable pedestal lamps giving a totally indirect system of general illumination. Localized lighting is provided by portable table and desk lamps.

School Rooms and Work Shops.—More experiments have been made and described¹⁶¹ before the German Illuminating Engineering Society on the lighting by gas of school rooms and work shops. The rooms in question varied in dimensions from 15 to 168 square meters in floor area. Various systems of lighting, including direct and indirect lighting, and lamps in specified reflectors arranged directly on the ceiling and at various heights below it were studied. The gas consumption, the diversity factor (maximum/minimum) and the illumination from the floor area were measured in each case. The method of mounting lights directly on the ceiling is referred to with special approval. In this case the best results were obtained with a clear globe or chimney and a white glass shade. In comparing the actual illumination with that obtained by calculation using Lambert's Formula it was found that in general for direct lighting the agreement was good,

¹⁵⁹ *Elec. Rev.*, Nov. 24, 1917, p. 891.

¹⁶⁰ *Jour. of Elec.*, March 1, 1918, p. 239.

¹⁶¹ *Elek. u. Masch.*, May 27, 1917, p. 252.

See also *Science Abstracts B*, Nov. 30, 1917, p. 429.

Ill. Eng. (Lond.), Sept., 1917, p. 235.

the observed results being usually 6 to 11 per cent. higher than the calculated, owing to reflection from walls and ceilings. The data bear out the impression that the illumination derived from a given consumption with indirect lighting is not far removed from half that obtainable from a good direct lighting installation, while a semi-indirect system occupies an intermediate position. In the discussion there was suggested the desirability of a more precise definition of terms such as diffused and reflected light and of the terms applied to shadows. It is interesting to note that our own Committee on Nomenclature and Standards has considered the definition of such terms for inclusion in its annual report.

Museums.—In the Progress Report for 1916 reference was made to the problems involved in the lighting of a natural history museum. Some of these have apparently¹⁶² been solved in the Academy of Sciences in San Francisco, the largest museum on the western coast. Two of the large exhibit halls, 180 by 60 ft. (55 by 18 m.), are devoted to the birds and mammals of the Pacific coast, which are shown in groups in compartments approximately 25 ft. (7.6 m.) wide by 13 ft. (4 m.) deep with a semi-circular background. A double system of skylights is used, a small one arranged some 4 ft. (1.2 m.) above a large one. This prevents sunlight from reaching the specimens directly and fading them. It also provides sufficient diffusion to give shadows such as might be found in the open. At night the effect is duplicated by the use of two 500-watt lamps with wide, flat reflectors located just to the rear of the upper skylight. The strength of the light and the diffusion through the second ground glass has been so carefully gauged that it is said to be difficult to tell when the lights are turned on in the late afternoon. The fact that artificial illumination does not fade specimens and its adaptability for spectacular features has been made use of in lighting a collection of ducks and geese. The effect of a sunset is enhanced by a special lamp and reflector which focuses the light on the painting so that this portion of the scene is actually brighter than the rest. The main body of the exhibit halls is lighted by the indirect system using troughs above the moulding.

A western agricultural college has adapted one of the larger type of artificial light units designed to give true color values to work

¹⁶² *Jour. of Elec.*, March 1, 1918, p. 228.

with a microscope on temporary mounts and stained prepared sections.¹⁶³ Suspended over the laboratory table it has been found to furnish light enough for four students, even for the high-power dry or the oil-immersion objectives.

Clubs.—Two garden foyers, one at each end of the promenade of a country club, have all their lighting supplied¹⁶⁴ by two 7 ft. (2.1 m.) floor pedestals each of which contains two 500-watt gas-filled tungsten lamps in silvered mirror reflectors. The ceilings are tinted a faint sky blue and the indirect system of illumination not only avoids shadows and glare but brings out clearly every detail of the decoration.

Theaters.—The growing appreciation of the value of color in creating the right atmosphere in places of amusement is shown in the lighting installation of one of the newest and largest moving-picture theaters in the west.¹⁶⁵ The semi-indirect system is used and each of the massive wrought metal fixtures contains globes of four colors, amber, white, red and blue. The four circuits are independently controlled and by the use of motor-driven dimmers any desired effect can be secured. Floor lights are used to assist patrons to find their seats. The exterior is floodlighted from concealed sources. In an eastern theater¹⁶⁶ incandescent gas lights are employed to produce a semi-indirect side wall illumination by the use of green reflector shades. The lights are about 15 ft. (4.5 m.) apart, give all the illumination needed and while burning all the time apparently do not interfere with the viewing of the pictures judging by the lack of complaints.

In an extensive report¹⁶⁷ by the Cinema Commission of Enquiry in England it is recommended that there be adequate illumination of the picture houses while the films are being shown and that an illumination of 0.1 foot-candle (0.107 mpc.) seems reasonable. It is further recommended that the front seats should be removed to at least 20 ft. (6 m.) from the screen. The London Illuminating Engineering Society was invited to co-operate with the Commission in regard to questions of lighting. The growing use of shaded lights placed on the sides of theatre chairs¹⁶⁸ to

¹⁶³ *Science*, Dec. 28, 1917, p. 641.

¹⁶⁴ *Sci. Amer.*, Jan. 19, 1917, p. 67.

¹⁶⁵ *Moving Picture World*, Dec. 22, 1917, p. 1798.

¹⁶⁶ *Amer. Gas Eng. Jour.*, Oct. 20, 1917, p. 359.

¹⁶⁷ *Ill. Eng. (Lond.)*, Sept., 1917, p. 233.

¹⁶⁸ *Moving Picture World*, Jan. 19, 1918, p. 375.

illuminate the steps of aisles indicates the extent to which specialized lighting is being pushed. Formerly this work was done, when done, by an usher carrying a pocket flash lamp.

Stores.—Dissatisfied with semi-indirect fixtures available, a large department store company has had designed¹⁶⁹ and installed a totally indirect system with some novel features. The fixture is made of plaster of paris in the form of an inverted bowl surrounded by a trough like a cornice, and the lamps lie in the trough. The dome is filigreed to admit light within it, giving the fixture a transparent appearance of lightness, while the exposed surfaces are a light ivory in color to match the ceilings and thereby be as inconspicuous as possible. Six hundred watts are used in each trough, the bowl is 30 in. (76 cm.) across and hung so that its lower edge is 29 in. (74 cm.) from the ceiling which, in turn is 21 ft. (6.4 m.) from the floor. The fixtures are centered in bays 24 by 16 ft. (7.3 by 4.9 m.) and are used throughout the main floor. It might be added that the dome-like character of the fixtures is consistent with the nickname of the store which is known as the "dome" store.

An adaptation of the camouflaged idea to show-case illumination is to be found¹⁷⁰ in a device which consists of three parts: (1) a nickel-finished reflector bowl which contains the lamp and acts as a base; (2) a plate glass shelf mounted on the base and adapted to display goods; and (3) an upright card rack for price cards and reading matter. The reflector has a hole in the bottom so that when set on a glass-top show-case it illuminates the goods below it and the source of light is not at once apparent. An installation¹⁷¹ in which an impression of direct lighting is given through the use of center fixtures with luminous-bowl reflectors, but which in reality is almost wholly one of indirect lighting, is to be found in a fur store. Reflectors countersunk into the tops of the wall cases help the reflectors in the center fixtures, to illuminate the ceiling.

Industrial Plants.—The National Commission for the Prevention of Blindness has issued¹⁷² a publication on eye hazards in industrial occupations which covers an investigation of some seventy plants, embracing many different kinds of industries.

¹⁶⁹ *Jour. of Elec.*, March 1, 1918, p. 225.

¹⁷⁰ *Sci. Amer.*, Sept. 29, 1917, p. 223.

¹⁷¹ *Elec. Merch.*, June, 1918, p. 310.

¹⁷² *Publication No. 12*, Nov., 1917, p. 121.

A section is devoted to industrial lighting and the "Codes of Lighting Factories and School Buildings," prepared by our Society, as well as the booklet "Light, Its Use and Misuse" are recommended to those seeking manuals of such information. There is advocated an illumination of the order of 4 lumens per square foot (4.3 mph.) as reasonably satisfactory for the generality of offices, and tables are given showing the watts per square foot required to yield this illumination both for gas and electric units, assuming various finishes for walls and ceilings.

Canadian practice in industrial lighting is illustrated¹⁷³ in that of a new steel plant. The three chief areas to be lighted are a Crane Bay (Furnace Room); Transformer Room; and Stock Yard. In the Crane Bay, a building approximately 75 by 600 ft. (23 by 183 m.), 1,000-watt gas-filled tungsten units are installed, spaced 45 ft. (13.7 m.) apart one way and 37½ ft. (11.3 m.) the other way. Steel enameled fluted deep bowl reflectors are used, the mounting height being about 40 ft. (12.2 m.). The average foot-candles obtained is approximately 2.8 (3.0 mph.). In the Transformer Room wall fixtures are employed. These consist of two 100-watt units in steel angle reflectors 18 in. (45 cm.) from the wall and 15 ft. (4.6 m.) from the floor, on approximately 11 ft. (3.4 m.) centers. A fairly uniform illumination of about 2.5 foot-candles (2.7 mph.) is the result. The Stock Yard is lighted to an intensity of about 1 foot-candle (1.07 mph.) at the loading platforms and 0.2 foot-candle (0.215 mph.) elsewhere. For this purpose 500-watt lamps are used, mounted in steel reflectors under the eaves of the buildings at a height of 36 ft. (11 m.) and spacing of 45 ft. (13.7 m.).

Side wall illumination in a power station has the advantage of easy accessibility to fixtures and nearness to the plane of illumination, a few feet above the floor. But the glare has been found disadvantageous and after experimenting, one company¹⁷⁴ has standardized on overhead lighting using 200-watt lamps mounted 33½ ft. (10.2 m.) above the floor. A resulting illumination of about 3⅓ foot-candles (3.6 mph.) is obtained and has been found satisfactory. A typical illustration of war time factory lighting by gas¹⁷⁵ is to be found in a large shoe factory.

A review of some of the most up-to-date installations around

¹⁷³ *Elec. News* (Canada), Oct. 1, 1917, p. 45.

¹⁷⁴ *N. E. L. A. Bul.*, Feb., 1918, p. 111.

¹⁷⁵ *Gas Age*, April 1, 1918, p. 321.

Portland, Ore., has shown¹⁷⁶ among others the following values for wattage per square foot in a lumber mill, a dock and its warehouse:

	Watts per square foot (Watts per sq. meter)	
Planing section, lumber mill.....	0.33	(0.0306)
Trimmer section, lumber mill.....	.37	(.0344)
Log deck, carriage and saw mill.....	.53	(.0493)
Main floor, dock .....	.16	(.0149)
Lower level, dock .....	.16	(.0149)
Warehouse connected with dock.....	.12	(.0111)

What is said to be the largest garbage disposal plant in the world has been placed in operation on Staten Island. Special attention has been given¹⁷⁷ to the lighting features. Among the novel problems to be solved was the proper illumination of the interior of the reducers. Two openings with suitable projections were cast in the top of the tanks. These are placed at such an angle that the light entering one is specularly reflected from the surface of the charge to the second opening. A parabolically shaped and polished aluminum reflector is fixed inside one opening with an aperture large enough to permit the closing of the hole by a steam-tight glass plate and gaskets. A low voltage 12-candlepower automobile headlight lamp, suitably protected, was found to give enough light when inserted through the opening in the reflector. The general lighting of the reducing room is given by 200-watt lamps in steel reflectors producing a specific power consumption of 0.33 watt per square foot (0.0306 watt per sq. m.) of floor area.

Transportation.—There has been compiled and is now available¹⁷⁸ a summary of present practice in railway coach lighting, including special reference to recent improvements. A standardized example¹⁷⁹ of this type of lighting is to be found in the use of semi-indirect bowls, the principal illumination in the car being obtained from light reflected from the ceiling.

Almost everyone who has travelled at night has been annoyed at times by light shining into the berth, coming from lamps left lighted to illuminate the aisles. The Pullman Company after considerable experimentation has developed¹⁸⁰ an installation

¹⁷⁶ *Jour. of Elec.*, June 1, 1918, p. 550.

¹⁷⁷ *Gen. Elec. Rev.*, Dec., 1917, p. 964.

¹⁷⁸ *Rlway Elec. Eng.*, Dec., 1917, p. 329.

¹⁷⁹ *Ibid.*, p. 378.

¹⁸⁰ *Ibid.*, Feb., 1918, p. 47.

which is expected to be a solution of this problem. The result has been accomplished by using low candlepower tungsten lamps in receptacles placed under the ends of alternate seats and shielded by green glass.

In the lighting of trolley cars the modern reflector method with the units arranged in a single row in the middle of the center deck has met the needs so well that it is being extensively used in new cars¹⁸¹ and many roads are changing over existing equipment, but there is one bad feature of street and interurban car lighting, much more in evidence in the latter case than in the former, namely, the effect of voltage fluctuations in the lighting circuits. To meet this difficulty a motor-generator set has been developed for use on interurban lines which it is claimed maintains the illumination without appreciable fluctuations and also preserves the continuity and intensity of the light from the headlights. By using a shunt or compensating device similar to those used with arc lamps, it has been found possible¹⁸² to cut down considerably the maintenance cost of lighting in electric railway cars.

FIXTURES.

One of the most striking evidences of the value of co-operation in any branch of industry is standardization. As the result of some months work on the problem at joint meetings of the Reflector Committee of the Association of Manufacturers of Electrical Supplies with committees of both reflector manufacturers and the engineering departments of various lamp companies, certain standard dimensions and specifications for porcelain-enameled steel dome reflectors have been adopted by the manufacturers. A quality of enamel has been adopted after a consideration of the efficiency for light purposes, and the elasticity. It is felt that the adoption of this standardized type of reflector is but the first step in the co-ordinated development of reflectors by the committees.

Reflectors.—There is a continual increase in the number of semi-indirect fixtures made up of two parts, an upper diffusing and reflecting glass canopy suspended over a diffusing, translucent bowl. These are designed primarily for stores and office

¹⁸¹ *Gen. Elec. Rev.*, Feb., 1918, p. 124.

¹⁸² *Elec. Rlway Jour.*, May 18, 1918, p. 978.

buildings. A similar construction, but made entirely of metal, is found in a group of fixtures designed for industrial plants. Then there is an extensive intermediate type in which the reflector is of metal and the bowl of glass, and this type is used both in stores and factories. Among the first named¹⁸³ is a new unit in which the upper reflector is made with a prismatic under surface, thereby, it is claimed, intensifying the light reflected downward. The use of a simple tripod holder permits the mounting of the translucent bowl without the use of holes or supporting rods.

Still another two-piece unit¹⁸⁴ has a very flat, shallow, translucent bowl and an inverted conical shaped reflector. The outside of this reflector is illuminated by light reflected from the bowl, while light is reflected from the interior of the cone to the ceiling which is also lighted by direct rays from the lamp. A variation¹⁸⁵ in this type has its reflector part made in three pieces. The top reflector and a bottom reflector are of opal diffusing glass, while the third part is a clear glass directing unit which is enclosed in the other two. A development of the two-piece into the one-piece reflector globe is found¹⁸⁶ in several units. One of these is equipped with an adjustable socket which permits of the use of lamps of different wattages from 100 to 400, without the use of tools or the dismantling of the unit. It also has a spring grip holder for the glassware.

A still further development¹⁸⁷ involving a saving in glassware is effected in a lamp of the ordinary gas-filled tungsten type, but having the lamp bulb itself made in the shape of a reflector. Plain white glass is used with ornamental markings of a color and style to harmonize with the room decorations.

A new unit¹⁸⁸ of the intermediate type uses a depolished enamel-coated steel reflector having a central opening. An inverted bell-shaped glass diffusing bowl is used and topped with another glass shade which transmits and diffuses light sent upward to the ceiling. Another unit¹⁸⁹ of this type has the metal spun over the glass, forming effectively one piece. An opening in

¹⁸³ *Elec. Record*, Jan., 1918, p. 33.

¹⁸⁴ *Ibid.*, June, 1918, p. 33.

¹⁸⁵ *Ibid.*, May, 1918, p. 36.

¹⁸⁶ *Ibid.*, July, 1918, p. 32.

¹⁸⁷ *Elec. Wld.*, April 20, 1918, p. 854.

¹⁸⁸ *Ibid.*, March 23, 1918, p. 647.

¹⁸⁹ *Elec. Merch.*, July, 1918, p. 44.

the bottom fits the large part of the lamp bulb, and with the latter frosted, a non-glaring unit is provided. A flat metal reflector is placed on the inside of the upper portion of the fixture. A modification¹⁹⁰ of this type uses an upper reflector of white satin-finished porcelain and claims additional improvement in its simplicity and small number of parts, the supports as well as the sockets being concealed inside the reflector. The bowl is made either of white translucent or of daylight glass.

In the list of metal reflectors reference may be made to one in which¹⁹¹ a porcelain enameled reflecting band is suspended from the upper reflector in such a way as to intercept all light within the angles of 45° and 85°. This light is reflected to the upper reflector of the same material and redirected downward to the working plane. Both parts are supported directly from the socket, but do not touch the lamp. Another fixture of this class¹⁹² uses a double cone-shaped lower part made up of a concentrating direct-lighting reflector below and above a reflector sending its light to the diffusing upper part of the unit. This fixture is of spun steel finished in white enamel. Special metal reflectors for use in illuminating billboards, wall signs and advertising display surfaces have been worked out.¹⁹³ The reflector is so shaped that it does not require the bending of conduit pipe to get the proper focus. A locking arrangement is also furnished.

Reflectors provided with suitable absorbing plates to be used with both gas and incandescent lamps, to provide light of a character suitable for color matching in stores, factories, etc., have been available¹⁹⁴ for some years, but new ones are still appearing.

Just as more attention has been paid to the proper installation of lighting for protective purposes, so the design of flood-lighting projectors has been made the subject of special study and they are now being designed on the basis of what they are to accomplish rather than on the principle of a searchlight. The former flat parabolic reflector is being replaced by a compound reflector and in some cases by two interchangeable reflectors.

¹⁹⁰ *Elec. Wld.*, April 6, 1918, p. 750.

¹⁹¹ *Sci. Amer.*, Dec. 15, 1917, p. 451.

¹⁹² *Elec. Rec.*, Jan., 1918, p. 33.

¹⁹³ *Elec. Rec.*, June, 1918, p. 30.

¹⁹⁴ *Ibid.*, May, 1918, p. 37.

Street Lighting.—A new street lighting fixture¹⁹⁵ for use with gas-filled tungsten lamps contains in addition to the usual supporting and connecting devices, a dome refractor of prismatic glass which collects light emitted upwards and redistributes it sideways and out into the street at an angle of 10° below the horizontal. This refractor is a development of one reported some time ago and consists of two clear glass bands one of which fits snugly inside the other. The inner part is girdled on its outer surface by horizontal prisms and the outer part has vertical diffusing prisms on its inner surface. The two prismatic surfaces come close together when the parts are sealed, leaving the inner and outer surfaces of the complete refractor entirely smooth, thus facilitating cleaning. A new enclosing globe used with this fixture is of clear glass stippled on the inside, thus producing diffusion and reduction in glare without much loss by absorption.

Specially designed for residential and park lighting service is a new ornamental unit which also utilizes the dome-shaped refractor above referred to for collecting and redistributing light emitted upward. A cone-shaped reflector at the bottom reflects light otherwise wasted and adds to the efficiency of the unit. The outer globe is made of stippled glass and consists of eight panels.

An addition¹⁹⁶ to street lighting fixtures is one for the high-current, high-candlepower series incandescent lamps. It is made of cast iron and is suitable either for an auto transformer or film cut-out socket. For the convenience of those having to do with the planning or providing of street lighting, data has been gathered together¹⁹⁷ showing the characteristics of a large number of standard type electric units, both incandescent and arc.

Public Buildings.—One of the recent developments in specialized lighting is that of the aisles of theaters and moving picture houses.¹⁹⁸ Several styles of units have been designed for this work.

Special seamless and dustless fixtures¹⁹⁹ have been designed for

¹⁹⁵ *Elec. Rev.* (U. S.), Nov. 3, 1917, p. 784.

Gen. Elec. Rev., June, 1918, p. 430.

¹⁹⁶ *Elec. Rev.* (U. S.), Jan. 5, 1918, p. 46.

¹⁹⁷ *Gen. Elec. Rev.*, Dec., 1917, p. 945.

¹⁹⁸ *Elec. Wld.*, Dec. 1, 1917, p. 1081.

¹⁹⁹ *Elec. News*, Nov. 1, 1917, p. 42.

Elec. Rec., Jan., 1918, p. 34.

use in hospitals. In these fixtures the canopies are screwed directly on the connecting tubes instead of being held by a collar. The sockets and shade holders, while equipped to take care of ventilation, are covered with a cap which fits snugly to the tube and shuts out dust while permitting of easy cleaning. The glassware used with these fixtures is chosen with particular reference to protection from glare and ease of cleaning. For the operating room the pendant unit consists of an upper reflector and lower bowl made of diffusing glass. The reflector is adjustable up and down, permitting the use of a concentrating effect when desired. A fixture designed especially for operating tables consists²⁰⁰ of an octagonal reflector 6 ft. (1.8 m.) in diameter, the various sections of which carry tubular single filament incandescent lamps. It is claimed that the reflected light is confined to the top of the table.

The requirements of garages in the way of special lighting have been recognized²⁰¹ in a number of styles of protected hand lamps and portable adjustable lamp standards which make it possible to illuminate all parts of the car, no matter where it is standing on the floor.

Ships.—Since the bulkhead or oyster-fitting holder for incandescent lamps was first used on a Cunard liner about the year 1884, little improvement has been made in this class of ship fitting until recently. The original form was intended for carbon filament lamps. A redesign has been worked out²⁰² to adapt this fitting for tungsten lamps. Apart from its application on board ship it is claimed that this fitting is well adapted for use in chemical works, mines and in places where it is important to protect the lamp from injury, mechanical or corrosive.

Glassware.—The idea of using the lamp bulb itself to support the reflector is utilized in an English invention.²⁰³ The reflector ring is of glass, silvered and provided with three adjustable copper clips to enable it to be fitted to the bulb. Tests by the National Physical Laboratory in England showed an increase in the light emitted in a direction toward the tip of the lamp, from 4 candlepower to 24 candlepower in the case of a 200-volt 40-

²⁰⁰ *Elec. Eng.*, June, 1918, p. 58.

²⁰¹ *Elec. Rec.*, July, 1918, pp. 33, 68, 69.

²⁰² *Elec. Times* (Lond.), Feb. 7, 1918, p. 100.

²⁰³ *Elec. Rev.* (Lond.), Dec. 14, 1917, p. 561.

watt lamp. The reflector is slipped on before the bulb is put into the socket.

For indirect lighting, bowls²⁰⁴ of semi-vitreous porcelain ware are now being made by a manufacturer of china ware. A glaze on the interior makes a very good reflecting surface. A new prismatic reflector for window lighting²⁰⁵ is of the asymmetric type and has an annular prismatic plate over the front half of the opening. New²⁰⁶ and artistic designs in lanterns are appearing.

An ornamental device to take the place of a service flag utilizes a flat alabaster globe²⁰⁷ about 8 in. (20.3 cm.) in diameter and lighted from within. It is mounted on an indestructible wood pulp pedestal with two molded eagles holding it. On one side a 3 by 5 in. (7.6 by 12.7 cm.) service flag is shown on the face of the bowl while extra stars are furnished to be attached as desired. A combination light and mirror, to be mounted on the front fender of an auto, is designed²⁰⁸ to save the use of two headlights and a rear light at night, and to provide a mirror for use by day. The lamp is cut in or out of circuit as the mirror is lowered or raised.

Additional data have been obtained²⁰⁹ on the deleterious effect of dust on lamp globes. The test was made in the grinding room of a large factory, the air in the room being moist and laden with steel dust. In order to secure average working conditions in a plant the lamps were cleaned one week after installation, but no other cleaning was done until all the lamps were taken down. With a week's accumulation of dirt the group of lamps showed an absorption ranging from 13.3 to 19.8 per cent. with an average of 16.3 per cent. At the end of three weeks the range was from 21.9 to 26.2 per cent. with an average of 19 per cent. Or at the end of a week over 16 per cent. more wattage was required to give the initial illumination and at the end of three weeks more than 22 per cent., thus indicating the economy to be derived in this particular case from frequent cleaning.

Accessories.—A synthetic metal the base of which is steel is

²⁰⁴ *Elec. Rec.*, Feb., 1918, p. 33.

²⁰⁵ *Central Station*, Sept., 1917, p. 66.

²⁰⁶ *Elec. Rec.*, July, 1918, p. 32.

²⁰⁷ *Ibid.*, Oct., 1917, p. 31.

²⁰⁸ *Ibid.*, July, 1918, p. 32.

²⁰⁹ *Ibid.*, Oct., 1917, p. 99.

now being used for lighting fixtures.²¹⁰ It is claimed that properly lacquered, such fixtures will not rust and are not subject to dents and injuries in transportation and erection. Efforts are being made to get away from the use of a screw and collar to hold caponies to their supporting tubes. By extending the canopy of a steel reflector²¹¹ arrangements are provided for locking the lamp so that it can only be removed by the use of a key. Loosening a nut at the top permits the whole reflector to be raised so that the upper part of the socket containing the locking device is exposed. Numerous connecting devices have been worked out²¹² for holding the parts of a two-piece unit together, and also for making up two-piece units from ordinary direct lighting reflectors.

In a great many factories and shops localized lighting is a necessity. For this purpose adjustable fixtures have been devised²¹³ the main feature of which is a friction disk. The maximum friction resistance is obtained by having the point of contact at the extreme outer edge of the disk, the centers being hollowed out and under tension. It is claimed that by the use of this arrangement a lamp may be easily adjusted to any position and will not be readily displaced.

Intended for use in chemical and dye works, factories and any place where the holder might be exposed to extreme dampness or to corrosive vapors, an acid and water-proof lamp holder has been designed.²¹⁴ The protective system consists of a vitreous porcelain shell with an acid-proof rubber shield that presses against the lamp thus hermetically closing off the lamp cap and holder from harmful attacks. Improvements²¹⁵ in sockets for incandescent electric lamps are found in a white porcelain type for use with a white enameled bracket, and in a socket cover which is shaped so that its lines blend with the line of the shade.

The toggle switch has for a number of years been the favorite in England for use where snap switches are employed in this country. The advantages of simple operation and direct indica-

²¹⁰ *Elec. Rec.*, Jan., 1918, p. 35.

²¹¹ *Elec. Rev.* (U. S.), Jan. 5, 1918, p. 43.

²¹² *Elec. Rec.*, April, 1918, pp. 54, 55.

²¹³ *Ibid.*, Jan., 1918, p. 42.

²¹⁴ *Elec. Times*, Nov. 22, 1917, p. 371.

²¹⁵ *Elec. Merch.*, July, 1918, p. 52.

tion of being open or closed has led to its introduction²¹⁶ here. Manipulation of this type of switch consists merely in the throw of a lever or toggle. In the *up* position the circuit is made, in the *down* position the circuit is open. A new time switch²¹⁷ for turning on or off the lights in electric signs, illuminated bill boards or other unattended lights that should burn for a specified time utilizes a weight descending by gravity. Twenty-four hours are consumed in the descent and contacts made at any desired point or points.

A new lamp-renewing device is arranged²¹⁸ for the removal or insertion of either multiple or series lamps which would otherwise require the use of a scaffolding or ladder. A jointed section pole is used and a three-jaw clutch operated by a cord.

PHOTOMETRY.

Instruments.—A new spectro-photometer²¹⁹ is distinguished by the application of a differential double slit, which is used to alter the relative intensities of the two sources of light to be compared. The use of the globe photometer²²⁰ for measuring the candle-power of gas-filled tungsten lamps has become standard practice in this country and its use in Germany is indicated in the description of an equipment in which the photometric device, while apparently containing no new principle, has been designed especially for this purpose. In a new stellar photometer,²²¹ light from an artificial source is reflected from a small silvered portion of a glass plate inserted at 45° in the path of the rays from an object glass to the eyepiece. The focus is adjusted so as to give an out-of-focus image in the center of which will be seen the illuminated silver disc. Adjustments are then made so that the artificial light is just invisible on the starlight. Difficulties owing to differences of color of starlight and the artificial comparison are remedied by interposing colored screens.

Further work on the photo-electric cell²²² in order to determine its possibilities in connection with photometry has shown that the

²¹⁶ *Sci. Amer.*, March 30, 1918, p. 271.

²¹⁷ *Ibid.*, Feb. 2, 1918, p. 110.

²¹⁸ *Elec. Wld.*, June 15, 1918, p. 1295.

²¹⁹ *Astrophys. Jour.*, Dec., 1917, p. 305.

²²⁰ *Elek. Zeit.*, April 5, 1917, p. 188.

²²¹ *Compte Rendus*, Feb. 18, 1918, p. 284.

²²² *Astrophys. Jour.* Nov., 1917, p. 241.

wavelength sensibility curve varies with time and hence the practical fabrication of cells screened to imitate the human eye is not as yet feasible.

Accessories.—An outgrowth of the use of ruled gratings²²³ for making neutral tint screens such as those used in photometry is to be seen in a new arrangement made by using small glass bars between which is laid a very thin sheet of some black opaque material. The maximum transmission is high and limited only by that of the optical glass used and the thickness of the interposed opaque material. The idea may also be used for a variable tint screen by using some transparent medium which can be colored in place of the opaque material. Altering the angle between the screen and incident beam of light, alters the amount of light traversing the opaque material in the first case or the colored medium in the second place. In the Progress Report for 1916 (page 749) reference was made to a luminosity curve solution to be used in conjunction with a thermopile to form a physical photometer. To conform with subsequent photometric measurements on color, the formula for the earlier solution has been changed. It is stated²²⁴ that the transmission of the new solution is probably very accurately represented by Kingsbury's formula for the visibility curve of the eye. Similar work has been carried on abroad.²²⁵ With the filter there worked out, and using a thermopile, the light efficiencies of various sources were compared. In the case of a black body at 1,395° K., the result obtained experimentally agreed with that obtained by calculation (0.0044 per cent.). The following table gives the efficiencies found for other sources.

Source	Photometric efficiency Watts per mhc. (Hefner)	Light efficiency (Per cent.)
Carbon filament	27.07	0.049
	4.12	0.33
	2.27	0.61
Tungsten filament	1.96	0.85
	0.81	2.10
Nernst	4.01	0.32
	1.88	0.80
Mercury arc	1.78	2.0
	0.28	6.5
Arc lamp		(9)

²²³ *Jour. Frank. Inst.*, Feb., 1918, p. 279.

²²⁴ *Jour. Frank. Inst.*, July, 1918, p. 121.

²²⁵ *Ann. d. Physik.*, March 11, 1918, p. 357.

Standards.—The use of acetylene for a standard in photometric photography has again been advocated.²²⁶ A French experimenter has repeated the work of Fouché described in 1905 and concludes that utilizing the entire flame for a single jet burner, of which the dimensions are defined, and pure acetylene gas, the intensity is a linear function of the consumption to within 1 per cent. all other things being equal. Data were obtained on the effect of pressure, humidity, types of burners and impurities. Using acetylene in cylinders dissolved in acetone and under pressure, it was found that the effect of the acetone could be neutralized by bubbling the gas through a layer of bisulphite of soda more than 5 cm. thick. The presence of the latter carried over into the flame did not appear to have any effect.

Additional experiments²²⁷ on the candlepower of the black body at the temperature of the melting point of platinum and using a platinum wedge method confirmed the previously obtained value of 58.4 candles per square centimeter as the brightness at this temperature, 2,037° K. It will be remembered that the candlepower of a black body at the temperature of the melting point of platinum has been proposed as a standard in photometry.

The Japanese have followed the example of England in adopting,²²⁸ as the unit of light, one-tenth of the luminous intensity of the 10 cp. Pentane lamp. As the result of 162 observations on the humidity correction factor, made at the Electrotechnical Laboratory, Department of Communications, Tokyo, a value 0.00638 was found which agrees with the English value more closely than with that of the U. S. Bureau of Standards. It is suggested that the difference may be due to the hood and ventilating duct used with the lamp when this factor was determined at the Bureau of Standards.

Computations.—It has been proposed²²⁹ to use a Fourier series for the determination of the polar curve of a light-source, radiating symetrically about its axis. The intensity would be measured in, say, five different directions, *viz.*, at 0°, 30°, 45°, 60° and 90° from the horizontal, and from these values the first

²²⁶ *Jour. of Acet. Lgt.*, Feb., 1918, p. 268.

²²⁷ *Jour. Frank. Inst.*, July, 1918, p. 122.

²²⁸ *Sci. Abs. A.*, March 31, 1918, p. 106.

Elec., April 12, 1918, p. 846.

²²⁹ *Elektrot. u. Masch.*, Feb. 17, 1918, p. 77.

five coefficients of the Fourier series could be calculated and hence the scp., lcp., or ucp. deduced. A theoretical method has been worked out²³⁰ for determining the distribution of illumination produced at a great distance by optical systems of the Fresnel type such as those used in lighthouses.

The use of the photometer²³¹ has been extended to the motion picture industry. In the most up-to-date laboratories, each lamp used in printing from the negative to the positive is photometered daily to insure a standard and uniform intensity.

PHOTOGRAPHY.

Motion Pictures.—The use of an image measuring $\frac{3}{4}$ by 1 in. (19 by 26 mm.) has been standard practice in the motion picture industry for the past ten years.²³² To overcome some of the inherent limitations involved in the use of such a restricted field of operation a new form of film which moves horizontally instead of vertically has been devised and special cameras for its use and projection have been worked out. The new image is 1 by $1\frac{1}{2}$ in. (26 by 38 mm.), and all the advantages of standard films such as tensile strength and the value of standardization in laboratory work, shipping and handling, are retained. The stage director is enabled to use a larger setting and with an area twice that of the ordinary image more scenery may be covered without reducing the size of the characters. Improvements have also been made²³³ in the ordinary type of projection machine for motion pictures, the most striking feature being the lateral projection and a construction such that with a duplex instrument six reels can be taken care of at a single loading, one machine controlling the starting and stopping of the other.

In order to enable the Government²³⁴ to study more intelligently some of the phases of shell action, work is being done on a special triplex camera which will take pictures at the rate of 500 per second. The apparatus is a combination of three picture-taking movements each of which photographs at the rate of 160 per second.

²³⁰ *Annales de Physique*, July-Aug., 1917, p. 51.

²³¹ *Sci. Amer.*, Dec. 8, 1917, p. 441.

²³² *Ibid.*, Jan. 26, 1918, p. 85.

²³³ *Ibid.*, March 23, 1918, p. 259.

²³⁴ *Moving Picture Wld.*, Dec. 22, 1917, p. 1781.

Color Photography.—A new method of color photography has been described.²³⁵ The difficulty of getting colored lines in sufficiently close juxtaposition has been overcome. A thin celluloid film is passed between two warmed rollers bearing fine grooves on their surfaces, similar fine grooves being thus found on the celluloid. The film is then coated with the coloring materials, two adjacent lines of different color being formed and these may be as fine as 0.03 mm. The other side of the film may be similarly treated with two other colors.

PHYSICS.

Light Sources.—Another analysis has been made²³⁶ of the efficiency of light production in the case of the firefly, taking into account such factors as the efficiency of food intake and its transformation into energy and the efficiency of the utilization of this energy. A simple apparatus has been worked out for separating the invisible ultra-violet radiation from that in the visible part of the spectrum using the method suggested by Wood.²³⁷ The apparatus is useful for determining the exact fluorescent colors of various compounds. The efficiency of various light sources is referred to under the heading "Photometry."

Materials.—Study has been made of the color, covering power and effectiveness of pigments.²³⁸ Effectiveness concerns the predominance of a pigment and is measured by the number of grams of white pigment with which one gram of the color in question must be mixed to make the color vanish. Prussian blue was found to have an effectiveness of 10,000, permanent green only 100. The grain size influences the three variables strongly.

The thermal expansion of tungsten has been studied²³⁹ over a range of temperatures from 300° to 2,700° K. (Centigrade + 273°), the values varying from 4.44×10^{-6} per degree to 7.26×10^{-6} per degree. It is pointed out that with the possible exception of molybdenum, tungsten has the lowest known coefficient of expansion of any metallic element for a given temperature range. Tests have also been made²⁴⁰ on the value and variation

²³⁵ *Elec.*, Jan. 4, 1918, p. 528.

²³⁶ *Jour. Frank. Inst.*, June, 1918, p. 775.

²³⁷ *Gen. Elec. Rev.*, Oct., 1917, p. 817.

²³⁸ *Sci. Amer. Supp.*, Feb. 2, 1918, p. 71.

²³⁹ *Phys. Rev.*, Dec., 1917, p. 638.

²⁴⁰ *Phys. Rev.*, April, 1918, p. 311.

with temperature of Young's modulus for a drawn tungsten wire. At 20° C. 35.5×10^{11} dynes per cm.² was found, the modulus decreasing uniformly with increase of temperature up to 1,000° at which temperature it was 32.3×10^{11} .

Experiments on the action of light on selenium²⁴¹ seem to show that the interior of the material is affected as well as the surface and hence the thickness of the selenium film in a cell is an influential factor in the effect of the light, a question which has been in dispute for some years. Data have been published²⁴² on the ultra-violet transmission of clear and cobalt blue glasses and²⁴³ on the transmission of white light by clear water. Confirmation of the assumption²⁴⁴ that the absorption by the earth's atmosphere of the ultra-violet radiation from the sun is due to ozone in the upper layers, is indicated by some work on this subject.

Constants.—Results of work on the optical constants and radiation laws of carbon²⁴⁵ have indicated that the constant μ in the radiation law $E = \mu T^4$ where E is the total radiation and T the absolute temperature, is a function of the temperature. For ordinary carbon the value of μ was found to vary from 4.02×10^{-5} at 1,000° K. to 4.67×10^{-5} at 4,500° K. For graphite the corresponding values of μ were 2.72×10^{-5} and 3.45×10^{-5} . A new determination of the constant σ ²⁴⁶ in the Stefan-Boltzman law using a modified Amerio receiver gave 5.60, or corrected for reflection 5.61, while further work on C_2 in the Wien radiation law has given a value²⁴⁷ of 14,400.

As a result of efforts to determine the emissive power of tungsten²⁴⁸ at high temperatures using black body radiation from a hollow tungsten filament, a relation has been found between the true temperature of tungsten and the black body brightness temperature. From these data and assuming the melting points of gold as 1,336° K. and palladium at 1,828° K., a temperature scale running from 1,700° K. to 2,350° K. has been proposed. In this work C_2 was taken as 14,350.

²⁴¹ *Elec.*, Nov. 2, 1917, p. 146.

²⁴² *Jour. Frank. Inst.*, July, 1918, p. 111.

²⁴³ *Gen. Elec. Rev.*, Aug., 1918, p. 577.

²⁴⁴ *Nature*, Oct. 25, 1917, p. 144.

²⁴⁵ *Ann. d. Phys.*, Feb. 8, 1918, p. 65.

²⁴⁶ *Sci. Abstr. A.*, March 31, 1918, p. 120.

²⁴⁷ *Phys. Rev.*, Nov., 1917, p. 515.

²⁴⁸ *Gen. Elec. Rev.*, Oct., 1917, p. 819.

A modification of the diffusion mercury-vapor vacuum pump²⁴⁹ consists essentially of two pumps of the Langmuir type. The apparatus only requires support from a water jet pump and is said to exhaust a volume of 1,500 cc. to less than 10^{-4} mm. in about 10 minutes.

LEGISLATION.

Factories.—The Committee on Labor of the Advisory Commission, Council of National Defense, has appointed²⁵⁰ a subcommittee on lighting to prepare a code of lighting for mills and workshops. The following points are to be kept in mind: (a) the conservation of the eyesight of employees, (b) safety, (c) increased labor efficiency, and (d) larger output and decrease in spoilage. A revision of the factory lighting code has been under way in Wisconsin²⁵¹ since last fall and the Pennsylvania Industrial Lighting Code was revised in February.²⁵² It is now issued in Vol. 1, No. 16, of the Safety Standards of the Industrial Board of that state. Similar revision was made in the New Jersey code in January. The proposed new code for Ohio referred to in last year's report has been prepared²⁵³ as provided under the direction of the Ohio Industrial Commission and is being discussed at public hearings and undergoing revision. Based largely upon the code prepared by this Society, a number of novel features have been introduced.²⁵⁴

Appreciating the necessity of some knowledge of illuminating engineering for the proper enforcement of the state codes of factory lighting, the Commissioners of Labor of the states of Pennsylvania and New Jersey arranged²⁵⁵ with the University of Pennsylvania for a course of instruction for all inspectors. This was provided in a series of lectures covering a two-day period, some 100 inspectors being present. Attention should be called to the School Lighting Code²⁵⁶ prepared by this Society, which after a consideration of many criticisms received, has been thoroughly revised.

²⁴⁹ *Jour. Amer. Chem. Soc.*, Oct., 1917, p. 2183.

²⁵⁰ *Elec. Wld.*, Jan. 5, 1918, p. 19.

²⁵¹ *Elec. Wld.*, March 23, 1918, p. 607.

²⁵² *TRANS. I. E. S. (U. S.)*, June 10, 1918, p. 45.

²⁵³ *Industrial Management*, Feb., 1918, p. 120.

²⁵⁴ *Elec. Wld.*, Feb. 2, 1918, p. 269.

²⁵⁵ *Elec. Wld.*, July 6, 1918, p. 11.

²⁵⁶ *Elec. News (Canada)*, March 15, 1918, p. 26.

Headlamps.—Reference should be made²⁵⁷ to the adoption by the Secretary of State of New York of a specification for the laboratory test of headlighting devices, formulated by our Committee on Automobile Headlights in conjunction with representatives from the Committee on Lighting Legislation and also the Society of Automotive Engineers. Because of the pressure upon railway companies to move war material and for other reasons, the Interstate Commerce Commission has extended the time for the equipment of locomotives with new high powered headlights.²⁵⁸ New locomotives placed in service after July 1, 1918, and those shopped for general or heavy repairs after that date, must be so equipped.

Foreign.—The French commission appointed to prepare revisions in the laws of weights and measures, has submitted a report.²⁵⁹ There is included a recommendation that the unit of light be the bougie-decimal defined as one-twentieth of the intensity of the Violle standard, and that the unit be maintained through the use of incandescent lamps as is done in this country, these lamps being deposited with the Conservatoire National des Arts et Métiers. The lumen is recommended as the unit of flux and the phot and lux as the units of illumination.

PHYSIOLOGY.

The visibility of radiation in the blue end of the visible spectrum has been studied²⁶⁰ by an optical pyrometer method. Results were obtained in the region from wave-length 0.41μ to 0.50μ . Using a modification of the Nutting monochromatic colorimeter, the flicker photometer principle and an acetylene flame as a source, more data on the same function but on the central part of the spectrum have been published.²⁶¹ Thirteen observers were employed and the maximum of visibility was found at 0.553μ . An entirely different procedure was followed²⁶² in another determination in which the direct comparison principle and a step by step method were used, a tungsten lamp forming the source and the energy being evaluated by determining the color temperature of

²⁵⁷ TRANS. I. E. S. (U. S.), July 20, 1918, p. 56.

²⁵⁸ *Rlway Elec. Eng.*, Jan., 1918, p. 1.

²⁵⁹ *Ann. de Phys.*, July-Aug., 1917, p. 12.

²⁶⁰ *Astrophys. Jour.*, March, 1918, p. 83.

²⁶¹ *Jour. Frank. Inst.*, May, 1918, p. 71.

²⁶² *Ibid.*, June, 1918, p. 829.

the source and computing the distribution by Planck's equation, allowing for dispersion, absorption by the optical system, and for scattered light. Twenty-nine observers participated. Combining these data with that just referred to covering the blue end of the spectrum and some data on the red end previously published,²⁶³ a complete visibility curve between wave-lengths 0.40μ and 0.76μ has been presented, with a maximum sensibility at approximately wave-length 0.556μ . Several experimenters have shown that the visibility curve of the eye (relative visibility plotted against wave-length) if corrected for the selective absorption of the ocular media, is very nearly symmetrical. It has been recently pointed out²⁶⁴ that the relation between frequency and corrected visibility gives an almost perfect symmetrical figure using the visibility data of Coblentz and Emerson.

Further work on the minimum radiation visually perceptible has yielded a value in one case²⁶⁵ 3.9×10^{-9} ergs per second, in another²⁶⁶ 1.25×10^{-9} as the quantity of light received by the eye at the limit of visibility. It has been found²⁶⁷ that the size of stimulus and exposure-time are factors in this problem and a study has been made of their effect. Three different kinds of retinal sensibility, threshold, contrast and glare, have been defined and made the subject of an investigation.²⁶⁸ Threshold sensibility for white light plotted logarithmically, gave practically a straight line. The experiments covered a range from 10^{-6} to 10^3 millilamberts. In regard to glare, curves were obtained showing the course of dark adaptation with white light and with different colors. The relation between the logarithm of the least brightness that appears approximately glaring and the logarithm of field brightness was found to be linear. The pupillary aperture changed in diameter from 2 to 7.4 mm. with a field brightness varying from 0 to 2,000 millilamberts. The flux density on the retina was calculated as 7.0×10^{-12} for a field brightness of 0.00001 millilambert and 1.1×10^{-4} for 2,000 millilamberts. There were also included measurements of the rate of dark adaption with different initial sensitizing brightnesses and the

²⁶³ *Astrophys. Jour.*, Nov., 1918, p. 285.

²⁶⁴ *Phys. Rev.*, June, 1918, p. 498.

²⁶⁵ *Astrophys. Jour.*, Sept., 1917, p. 167.

²⁶⁶ *Astrophys. Jour.*, Nov., 1917, p. 296.

²⁶⁷ *Ibid.*, April, 1918, p. 141.

²⁶⁸ *Phys. Rev.*, Feb., 1918, p. 81.

work on the pupillary aperture was carried out both for binocular and monocular vision.

The lagging of different color-impressions received by the eye with respect to each other has been called "Visual diffusivity." Experiments on this subject have led to results²⁶⁹ of interest from the standpoint of the three-color theories of vision. A mixed yellow has been decomposed into its red and green components by a rapid oscillatory movement of the color. It was found that monochromatic color could not be thus decomposed. A preliminary study has been made²⁷⁰ of the power of the eye to sustain clear and comfortable seeing with light from various illuminants ranging from a kerosene flame to the blue-bulb tungsten lamp.

The Forest Service in co-operation with the Department of Psychology of the University of Wisconsin, has made a study²⁷¹ of the effect of color of paper and the glare upon eye-fatigue. The results indicate no difference in the latter produced by reading from newsprint paper manufactured from tamarack as compared with that from spruce. The tamarack produces a darker colored paper.

The use of a thermo-couple placed at the focus of a lens or parabolic reflector²⁷² as a possible method for providing blind people with means for detecting the presence of light such as that from a window, a lamp or the sun is suggested. A special type of telephone receiver would be used in conjunction with the apparatus. The results of a three months' test to determine the relative hygienic effects of gas and electric lighting indicated no difference²⁷³ from the standpoint of condition of the body, percentage of CO₂ in the air, and rise in room temperature at the breathing level.

The ophthalmic surgeons of Great Britain and Ireland have decided to set up a standing advisory council²⁷⁴ on all matters relating to eyesight. The acting and past presidents of the Ophthalmology Society and of the section of ophthalmology of the Royal Society of Medicine will be permanent members.

²⁶⁹ *Phil. Mag.*, May, 1918, p. 413.

²⁷⁰ *Amer. Jour. of Ophthal.*, April, 1918, p. 252.

²⁷¹ *Railway Elec. Eng.*, Jan., 1918, p. 8.

²⁷² *Elec. Rev.* (Lond.), Feb. 22, 1918, p. 184.

²⁷³ *Gas Age*, Feb. 1, 1918, p. 133.

²⁷⁴ *Elec.*, May 10, 1918, p. 22.

ILLUMINATING ENGINEERING IN GENERAL.

The difficulties encountered in advancing the cause of illuminating engineering are emphasized in an address²⁷⁵ before the London Society in which reference was made to the efforts put forth to get the government to utilize the resources of the Society. It will be remembered that our own Society has been given an opportunity to co-operate with the Council of National Defense through representation on the National Committee on Lighting.

Daylight Saving.—The daylight saving bill was signed by the President, March 19th.²⁷⁶ It provided for setting all clocks forward an hour on the last Sunday in March and turning them back again the last Sunday in October. Thus the United States identifies itself in this regard with the twelve European countries which have already tried out the plan and have found it successful. In view of the final result it is interesting to note²⁷⁷ that at a meeting of the American Astronomical Society last August an informal expression of opinion showed 22 against it, 18 for it, and 6 neutral. On the other hand the general medical board of the Council of National Defense²⁷⁸ at its regular January meeting passed a resolution introducing the plan of daylight saving and agreeing to lend its influence in securing the passage of the law. Efforts were made²⁷⁹ while the bill was under consideration to have the plan extended throughout the year in order to create a greater diversity between the daily power and lighting loads of central stations. The Executive Committee on Daylight Saving²⁸⁰ of the United States Chamber of Commerce was unanimous in its agreement that daylight saving ought to be a permanent measure to operate through the entire year.

An analysis of data from Public Utilities in the middle west for the month of April indicated²⁸¹ an average reduction in output in kw-hrs. due to the daylight saving of about 5 per cent. In general the reports which have been published²⁸² showing the effect of daylight saving on the load curves of other central

²⁷⁵ *Elec.*, Jan. 25, 1918, p. 598.

²⁷⁶ *Cleveland Plain Dealer*, March 20, 1918, p. 1.

²⁷⁷ *Science*, Nov. 9, 1917, p. 467.

²⁷⁸ *Ibid.*, Jan. 25, 1918, p. 87.

²⁷⁹ *Elec. Rev. (U. S.)*, Jan. 19, 1918, p. 116; Feb. 9, p. 236, and April 6, p. 733.

²⁸⁰ *Elec. Wld.*, April 20, 1918, p. 838.

²⁸¹ *Elec. Wld.*, May 11, 1918, p. 972.

²⁸² *Ibid.*, July 6, 1918, p. 18.

stations in this country note an improvement. In Canada,²⁸³ after two months operation, a survey revealed little if any change either in the revenue or operating conditions. So popular has the daylight saving scheme proved in England²⁸⁴ that upon urgent request, the date for starting was advanced so as to give five weeks more of the extended daylight period. A committee has been appointed to make plans²⁸⁵ for the adoption of the daylight saving scheme in Hawaii. It is said that sugar planters in some districts have practiced this for some years, the advance in time ranging on various estates from 15 minutes to an hour.

Light Sources.—From experiments²⁸⁶ in crossing the two substances which are responsible for light production in fireflies, it has been deduced that the oxidizable substance and hence the source of light, is what is called photogenin by one experimenter, or luciferose as it is called by another experimenter. How the other substance, photophelein, acts to aid in producing the light is still hypothetical but it is suggested that it may cause a dispersion of colloidal particles of the photogenin and thereby increase the surface and permit auto-oxidation. Reference to the efficiency of light production by the firefly will be found under the heading "Physics."

Two trees,²⁸⁷ the wood of which has the property of giving to water a marked fluorescence, have been rediscovered. One is found in Mexico, the other in the Philippines.

A large number of inorganic and organic substances have been examined²⁸⁸ or triboluminescence or the luminosity shown when crystals are crushed in the dark. The minimum size of particle which will show this phenomenon is 0.001 mm. for zinc sulphide, 0.06 for quartz and uranium nitrate, 0.14 for sugar, 0.7 for white fluorspar. Very fine powders do not show it. It becomes more distinct as a rule when the substance is cooled down (to say,—80° C.) and the color changes.

A very novel method of producing the so-called "Artificial Daylight" has been suggested²⁸⁹ and tested by an experimenter

²⁸³ *Elec. News*, July 15, 1918, p. 24.

²⁸⁴ *Gas Jour.*, Feb. 26, 1918, p. 388.

²⁸⁵ *Sci. Amer.*, Nov. 3, 1917, p. 325.

²⁸⁶ *Science*, Sept. 7, 1917, p. 241.

²⁸⁷ *Pop. Science Monthly*, April, 1918, p. 576.

²⁸⁸ *Phys. Zeit.*, Feb. 15, 1918, p. 78.

²⁸⁹ *Phys. Rev.*, June, 1918, p. 502.

who uses an artificial source such as an acetylene flame or a vacuum or gas-filled tungsten lamp, and passes the light through two nicol prisms with a crystalline quartz plate between them. The path of the light is made parallel to the optical axis of the quartz, and the thickness of the latter as well as the angle between the principal planes of the nicols must be properly chosen. An extension of the use of radium compounds²⁹⁰ to illuminate key holes, clock dials, etc., is found in a set of flat radium-treated discs to be attached to the dials of clocks at the five minute points. A pair of hands similarly treated makes it possible to tell easily the time in the dark.

Applications.—For night flying. navigation lights on the machines themselves have been found indispensable.²⁹¹ In the British machines used to defend London against air raids, they are placed on the edge of the lower plane and are under the control of the pilot. They serve as a guide in squadron formation. In some cases variegated colored lights are used for signalling between the units of invading squadrons. For landing the British home pilots make use of a flare which is used to illuminate the ground below.

There has been no generally recognized "Scale of Seeing" applicable for daylight use by astronomers. In connection with observations on the sun, the desirability of such a standard scale has been apparent,²⁹² and work on it has been begun.

Of the many uses of artificial light one of the most unique²⁹³ is in connection with the stimulation of plant growth. Recent experiments along this line showed that with a very intense illumination, 700 lumens per square foot (0.75 phot), approaching the magnitude of sunlight illumination, the rapidity of the growth and development of the plants experimented with was approximately double. The experiments suggest the possibility of using the idea commercially for the development of flowers such as Easter lilies which are required at a certain time.

The use of electric or other lights as an aid to fish catching²⁹⁴ is old, but a western hatchery has used them for aids in feeding.

²⁹⁰ *Pop. Science Monthly*, Feb., 1918, p. 221.

²⁹¹ *Sci. Amer.*, Feb. 23, 1918, p. 163.

²⁹² *Sci. Amer. Sup.*, July 6, 1918, p. 9.

²⁹³ *Gen. Elec. Rev.*, March, 1918, p. 232.

²⁹⁴ *Elec. Rev. (Lond.)*, May 3, 1918, p. 424.

The lights attract bugs and many fall into the water where they are eaten by the fish.

Efforts are still being made²⁹⁵ to correlate color and music. A recital of modern music was given recently in a New York theatre where the lights were part of an experiment in "projection of a melodic, harmonic, rhythmic or mood conception in tone" with the help of "relative atmospheric setting."

Societies.—An illuminating engineering society has been formed in Japan²⁹⁶ and the first two numbers of the transactions of the society have been issued. Among the subjects discussed have been the Life of Incandescent Lamps, Indirect Lighting, The Spherical Photometer, etc. It is a pleasure to record the fact that this society, together with the Japanese Electric Society, showed its spirit of hospitality and co-operation, its respect, confidence and friendliness toward this country by the entertainment last fall of the president of the A. I. E. E., and other American business men. The British I. E. S. has two committees working on experiments²⁹⁷ on flares and parachute lights and on luminous gunsights for a Government Department.

The French Committee of the International Commission on Illumination had a meeting²⁹⁸ on November 10th at which routine matters were disposed of. At a subsequent meeting of the Committee,²⁹⁹ held in Paris on April 18th, there was a discussion of the propositions sent by this Society regarding photometric quantities and units and their application in the industries. It was decided to reserve decision until the publication of the translation of the information in French and a note by M. Blondel in reference to it. It was reported that French lamp manufacturers are disposed to adopt the lumen, if convenient and practical apparatus for the measurement of luminous flux, notably integrating spheres, can be procured.

While information from Germany is very meagre it appears that the German Illuminating Engineering Society is still holding meetings.³⁰⁰ The fourth annual meeting of the Society was held September 15, 1917. Papers were presented by Dr. Bloch on

²⁹⁵ *N. E. L. A. Bul.*, Dec., 1917, p. 898.

²⁹⁶ *Ill. Eng.* (Lond.), April, 1918, p. 101.

²⁹⁷ *Elec. Rev.* (Lond.), June 7, 1918, p. 543.

²⁹⁸ *Rev. Gen. d'Elec.*, Nov. 17, 1917, p. 761.

²⁹⁹ *Ibid.*, May 11, 1918, p. 674.

³⁰⁰ *Ill. Eng.* (Lond.), Sept., 1917, p. 240.

"Uniform Evaluation or Marking of Sources of Light," and by Dr. Halbertsma on "Diffusion of Light as a Means of Reducing the Brightness of Artificial Illuminants." The eleventh formal meeting³⁰¹ was called for January 1, 1918. The program comprised reports and a discussion on the effect of the coal restrictions on lighting. A conference was arranged³⁰² between the German Society and the Berlin Architects Association in order to take up practical lighting problems. A joint committee was appointed to consider such questions as the drawbacks of insufficient illumination, the effects of glare, the waste of light through the use of unsuitable decorative devices or inefficient fixtures, the intensity of illumination required for various classes of work, the planning of buildings with a view to the provision of sufficient natural illumination during working hours, etc. The value proposed by Cohn in 1885, 25 meter-Hefners (approximately 2 foot-candles) as a satisfactory illumination for reading and writing will be reconsidered and a rise to 50 meter-Hefners may be recommended.

By order of the President of the United States,³⁰³ the National Academy of Sciences has been requested to perpetuate the National Research Council which was formed in 1916, as a measure of national preparedness.

LITERATURE.

The following books have been reviewed:

"Lighthouses and Lightships of the United States," by Geo. R. Putnam. Houghton, Mifflin Co., New York and Boston, 1917. 8vo, 321 pp.

"Miniature Electric Light," by B. E. Jones. London, Cassell & Co. 156 pp.

"The Lighting Art," by M. Luckiesh. New York, McGraw-Hill Book Co., Inc., 1917.

DISCUSSION.

F. E. CADY: Owing, probably, to the fact that we have made it a practice of including references to the sources of most of our information, there has arisen an idea on the part of some members that this report is merely a review of the literature on

³⁰¹ *Gas Jour.*, Jan. 1, 1918, p. 14.

³⁰² *Ill. Eng.* (Lond.), March, 1918, p. 70.

³⁰³ *Science*, May 24, 1918, p. 511.

the subject of illumination. It is quite true that what is published in the technical and scientific press is made the basis of the report and this is natural since the very existence of this class of literature depends upon its ability to present to its readers current progress. There is published in the *TRANSACTIONS* a monthly statement in which an effort is made to give a list of practically all articles of interest to the Society. But in the annual report, only those subjects are referred to, which, in the view of the committee, indicate either changes in conditions or improvement—progress, in the sense of improvement, and not merely progress in the sense of activity. It is recognized that the value of a report of this character depends largely on its impartiality and it is felt that by confining the material as far as feasible to what has been published, doubt as to bias on the part of the members of the committee will be reduced to a minimum.

During the past year, we have witnessed a rather curious antithesis, in that the war has caused in one direction an enormously increased use of light, due to the demands of factories engaged in all sorts of war work; in another direction, a very considerable decrease, due to the restrictions imposed by the Government for the sake of saving fuel.

A. H. TAYLOR: I would like to comment on one part of this report. On page 498 attention is called to the fact that in the Japanese investigations of pentane lamps the water-vapor correction factor obtained from their experiments agreed more closely with that obtained at the National Physical Laboratory than with the value found at the Bureau of Standards. At all three laboratories it was assumed that the correction for temperature was so small as to be negligible. Mr. Crittenden, of the Bureau of Standards, has obtained from Japan and England detailed data regarding the temperatures prevailing during the experiments, and finds that the three laboratories are in very close agreement when a temperature correction of approximately 0.1 per cent. per degree Centigrade is applied to the observed data.

REPORT OF THE COMMITTEE ON NOMENCLATURE AND STANDARDS OF THE ILLUMINATING ENGI- NEERING SOCIETY FOR THE YEAR 1918.*

In the following paragraphs those which have been altered by revision during the past year are marked with an "R" and new paragraphs are marked with an "N."

1. Light.—The term light is used in various ways:

(1) To express the visual sensation produced normally when radiant flux ($q. v.$) within the proper limits of wave-length, of sufficient intensity and of sufficient duration, impinges on the retina.

(2) To express the luminous flux ($q. v.$) which produces the visual sensation.

(3) By extension, even to express the radiant flux of any wave-length throughout the entire spectrum (*e. g.*, ultra-violet light).

2. Radiant flux, ϕ , is the rate of flow of radiation evaluated with reference to energy, and is expressed in ergs per second or in watts.

3. Luminous flux, F , is the rate of flow of radiation evaluated with reference to visual sensation, and is expressed in lumens.

4. Visibility, K_λ , of radiation of a particular wave-length is the ratio of the luminous flux at that wave-length to the corresponding radiant flux.

Defining equation:

$$K_\lambda = \frac{F_\lambda}{\phi_\lambda} .^1$$

5. The Mechanical equivalent of light is the ratio of radiant flux to luminous flux for the wave-length of maximum visibility, and is expressed in ergs per second per lumen, or in watts per lumen. It is the reciprocal of the maximum visibility.²

* A report presented at the twelfth annual convention of the Illuminating Engineering Society, at New York, on October 10, 1918.

¹ A table of recommended values of visibility is given in §70.

² This term has been used in a variety of senses. As here defined it refers only to the minimum mechanical equivalent of light. The reciprocal of this quantity is sometimes called the luminous equivalent of radiation. A recommended numerical value is given in § 69.

6. **Luminosity** of a particular wave-length is the product of the visibility of that wave-length and the corresponding ordinate of the spectral curve of radiant flux, and is represented by the ordinate of the spectral curve of luminous flux. This curve is called the spectral luminosity curve and is different with different sources.

7. The **Luminous efficiency** of any source is the ratio of the luminous flux to the radiant flux from the source and is expressed in lumens per watt.

8. **Luminous intensity**, I , of a source of light in a given direction is the solid angular density of the luminous flux emitted by the source in the direction considered, when the flux involved acts as far as computation and measurements are concerned, as if it came from a point. Or, it is the flux per unit solid angle from that source in the direction considered. The flux from any source of dimensions which are negligibly small by comparison with the distance at which it is observed, may be treated as if it were emitted from a point.

Defining equation:

$$I = \frac{dF}{d\omega}$$

or, if the intensity is uniform,

$$I = \frac{F}{\omega}$$

where ω is the solid angle.

9. **Illumination**, E , of a surface at any point is the luminous flux density on the surface at that point, or the flux per unit of intercepting area.

Defining equation:

$$E = \frac{dF}{dS}$$

or, when uniform,

$$E = \frac{F}{S}$$

where S is the area of the intercepting surface.

10. Candle is the unit of luminous intensity maintained by the national laboratories of France, Great Britain and the United States.³

11. Candlepower, cp., is luminous intensity expressed in candles.

12. Lumen, l., is the unit of luminous flux equal to the flux emitted in a unit solid angle (steradian) by a point source of unit candlepower.⁴

13. Lux is a unit of illumination equal to one lumen per square meter. Using the centimeter as the unit of length, the unit of illumination is one lumen per square centimeter, for which Blondel has proposed the name **phot**. One millilumen per square centimeter (**milliphot**) is more useful as a practical unit. One **foot-candle** is one lumen per square foot, and is equal to 1.0764 milliphots. The milliphot is recommended for scientific records.

14. Exposure is the product of an illumination by the time. The **microphot-second** (0.000001 phot-second) is a convenient unit for a photographic plate exposure.

R **15. Brightness** of an element of a luminous surface may be expressed in either of two ways: (a) in terms of intensity, I , (b) in terms of flux, F .

(a) Brightness in terms of the luminous intensity I (or candlepower) per unit of projected area of the surface (candlepower brightness) corresponds to the defining equation

$$b_I = \frac{dI}{dS \cos \theta}$$

where θ is the angle between the normal to the surface and the line of sight.

(b) Brightness in terms of the flux, F , proceeding from a unit area of the surface, on the assumption that the surface is a perfect diffuser; *i. e.*, that it obeys the cosine law of emission or reflection, (lumen brightness) corresponds to the defining equation

$$b_F = \frac{dF}{dS}$$

(perfect diffusion assumed).

The units in which brightness is measured according to (a) and (b) differ only in numerical value. See paragraph 16.

³ This unit, which is used also by many other countries, has frequently been referred to as the international candle.

⁴ A uniform source of one candlepower emits 4π lumens.

R **16. Lambert, L**, is the unit of brightness in the lumen system. The lambert is the brightness of a perfectly diffusing surface emitting or reflecting one lumen per square centimeter. For most purposes the **millilambert**, 0.001 lambert, is the preferable practical unit.

To say that the brightness of a surface as viewed from a given point is n lamberts, signifies that its brightness is the same as that of a perfectly diffusing surface emitting or reflecting n lumens per square centimeter.

In practice no surface obeys exactly the cosine law of emission or reflection; hence the brightness of a surface generally is not uniform but varies somewhat with the angle at which it is viewed.

A perfectly diffusing surface emitting one lumen per square foot will have a brightness of 1.076 millilamberts.

Brightness expressed in candles per square centimeter may be reduced to lamberts by multiplying by $\pi = 3.14$.

Brightness expressed in candles per square inch may be reduced to lamberts by multiplying by $\pi/6.45 = 0.487$.

17. Quality of luminous flux is that property of luminous flux determined by its spectral distribution.

18. Color of luminous flux is the subjective evaluation by the eye of the quality of luminous flux. Any color can be expressed in terms of its hue and saturation.

19. Hue is that property of color by which the various spectral regions are characteristically distinguished. All colors except purples and white may be matched in hue with spectral colors. In the case of a purple, the spectral hue which is complementary to the hue of the purple is ordinarily used for scientific designation.

20. Two hues are complementary if they may be mixed to produce white.

White may be considered as a color having no hue. By the mixture of luminous fluxes of two or more hues properly chosen both as to hue and intensity, a resultant luminous flux may be obtained which has the color white. Whenever luminous fluxes of two or more hues are mixed, the resultant luminous flux,

though it may have some dominant hue, will ordinarily be evaluated subjectively as having an admixture of white.

21. Saturation of a color is its degree of freedom from admixture with white. Monochromatic spectral light may, for purposes of measurement, be considered as having a saturation of 100 per cent. As white light is added, the saturation decreases, until, when the hue entirely disappears, the saturation is zero. White therefore is the limiting color having no hue and zero saturation.

SURFACES AND MEDIA MODIFYING LUMINOUS FLUX.

N **22. Diffusing** surfaces and media are those which break up the incident flux and distribute it more or less in accordance with the cosine law, as for example, white plaster and opal glass.

N **23. Redirecting** surfaces and media are those which change the direction of the luminous flux in a definite manner; as for example, a mirror or a lens.

N **24. Scattering** surfaces and media are those which redirect the luminous flux and break it up into a multiplicity of separate pencils; as for example, ripple glass, reflecting or transmitting.

25. Reflection factor⁵ of a body, ρ , is the ratio of the flux reflected by the body to the flux incident upon it. The reflection from a body may be regular, diffuse or mixed. In regular reflection the flux is reflected at an angle of reflection equal to the angle of incidence. In diffuse reflection the flux is reflected in all directions. In perfectly diffuse reflection, the distribution of the reflected flux is in accordance with Lambert's cosine law. In most practical cases, there is a superposition of regular and diffuse reflection.

26. Regular reflection factor of a body is the ratio of the regularly reflected flux to the incident flux.

27. Diffuse reflection factor of a body is the ratio of the diffusely reflected flux to the incident flux.

28. Absorption factor⁵ of a body, a , is the ratio of the flux absorbed by the body to the flux incident upon it.

29. Transmission factor⁵ of a body, τ , is the ratio of the flux transmitted by the body to the flux incident upon it.

$$\rho + a + \tau = 1$$

ILLUMINATION.

N 30. Unidirectional illumination on a surface is that produced by a single light source of relatively small dimensions. It is characterized by the fact that a small opaque object placed near the illuminated surface casts a sharp shadow.

N 31. Multidirectional illumination on a surface is that produced by several separated light sources of relatively small area. It is characterized by the fact that a small opaque object placed near the illuminated surface casts several shadows.

N 32. Diffused illumination is that produced either by primary or secondary light sources having dimensions relatively large with respect to the distance from the point illuminated, and scattering light in all directions. It is characterized by relative lack of shadow. Diffused illumination may be derived principally from a single direction as in the light from a skylit window, or from all directions as in the open air. Perfectly diffused illumination on a surface is shadowless.

In any practical case of illumination on a surface there is usually a mixture of the above types.

33. Coefficient of utilization of an illumination installation on a given plane is the total flux received by that plane divided by the total flux from the lamps illuminating it. When not otherwise specified, the plane of reference is assumed to be a horizontal plane 30 inches (76 cm.) from the floor.

34. Variation factor of an illumination installation is the ratio of either the maximum or minimum illumination on a given plane to the average illumination on that plane.

35. Variation range of illumination on a given plane is the ratio of the maximum illumination to the minimum illumination on that plane.

⁵ These terms are introduced to replace the more commonly used terms, Coefficient of reflection, Coefficient of absorption, Coefficient of transmission, which latter terms refer to the specific properties of materials rather than to the behavior of bodies under specified conditions, such as angle of incidence, etc.

36. Hemispherical ratio for a given lighting unit is the ratio of the luminous flux in the upper hemisphere to that in the lower hemisphere.

37. Brightness ratio is the ratio of the brightness of any two surfaces. When the two surfaces are apposed, the brightness ratio is commonly called the "brightness contrast."

ILLUMINANTS.

38. Lamp—a generic term for an artificial source of light.

The following definition has been agreed to conjointly with the Lighting Division of the Standards Committee of the Society of Automotive Engineers:

39. An electric incandescent lamp is a light source consisting of a glass bulb containing a filament electrically maintained at incandescence. A lighting unit consisting of an electric incandescent lamp with shade, reflector, enclosing globe, housing, or other accessories, is also commonly called a "lamp." In such cases in order to distinguish between the assembled lighting unit and the incandescent light source within it, the latter is often called a "bulb," especially in the automobile industry.

40. The output of all illuminants should be expressed in lumens.

41. Illuminants should be rated upon a lumen basis rather than a candlepower basis.

42. Lamp efficiency is the ratio of the luminous flux output to the power input.

43. The lamp efficiency or specific output of electric lamps should be stated in terms of lumens per watt and that of illuminants depending upon combustion should be stated in lumens per British thermal unit per hour.

44. The power consumption of auxiliary devices which are necessarily employed in circuit with a lamp should be included in the input of the lamp. For example, the watts lost in the ballast resistance of an arc lamp are properly chargeable to the lamp.

45. The specific consumption of an electric lamp is its watt consumption per lumen. "Watts per candle" is a term used commercially in connection with electric incandescent lamps, and denotes watts per mean horizontal candle.

46. Life Tests.—Electric incandescent lamps of a given type may be assumed to operate under comparable conditions only when their lumens per watt consumed are the same. Life test results, in order to be compared, must be either conducted under, or reduced to, comparable conditions of operation.

47. In comparing different luminous sources, not only should their candlepower be compared, but also their relative form, brightness, distribution of illumination and character of light.

48. Lamp Accessories.—A **reflector** is an appliance the chief use of which is to redirect the luminous flux of a lamp in a desired direction or directions.

49. A shade is an appliance the chief use of which is to diminish or to interrupt the flux of a lamp in certain directions where such flux is not desirable. The function of a shade is commonly combined with that of a reflector.

50. A globe is an enclosing appliance of clear or diffusing material the chief use of which is either to protect the lamp or to diffuse its light.

PHOTOMETRY.

51. Primary luminous standard is a recognized standard luminous source reproducible from specifications.

52. Representative luminous standard is a standard of luminous intensity adopted as the authoritative custodian of the accepted value of the unit.

53. Reference standard is a standard calibrated in terms of the unit from either a primary or representative standard and used for the calibration of working standards.

54. Working standard is any standardized luminous source for daily use in photometry.

55. Comparison lamp is a lamp of constant but not necessarily known candlepower against which a working standard and test lamps are successively compared in a photometer.

56. Test lamp, in a photometer, is a lamp to be tested.

57. Performance curve is a curve representing the behavior of a lamp in any particular (candlepower, consumption, etc.) at different periods during its life.

58. Characteristic curve is a curve expressing a relation between two variable properties of a luminous source, as candlepower and volts, candlepower and rate of fuel consumption, etc.

59. Horizontal distribution curve is a polar curve representing the luminous intensity of a lamp, or lighting unit, in a plane perpendicular to the axis of the unit, and with the unit at the origin.

60. Vertical distribution curve is a polar curve representing the luminous intensity of a lamp, or lighting unit, in a plane passing through the axis of the unit and with the unit at the origin. Unless otherwise specified, a vertical distribution curve is assumed to be an average vertical distribution curve, such as may in many cases be obtained by rotating the unit about its axis, and measuring the average intensities at the different elevations. It is recommended that in vertical distribution curves, angles of elevation shall be counted positively from the nadir as zero, to the zenith as 180° . In the case of incandescent lamps, it is assumed that the vertical distribution curve is taken with the tip downward.

61. Mean horizontal candlepower of a lamp is the average candlepower in the horizontal plane passing through the luminous center of the lamp.

It is here assumed that the lamp (or other light source) is mounted in the usual manner, or, as in the case of an incandescent lamp, with its axis of symmetry vertical.

62. Mean spherical candlepower of a lamp is the average candlepower of a lamp in all directions in space. It is equal to the total luminous flux of the lamp in lumens divided by 4π .

63. Mean hemispherical candlepower of a lamp (upper or lower) is the average candlepower of a lamp in the hemisphere considered. It is equal to the total luminous flux emitted by the lamp in that hemisphere divided by 2π .

64. Mean zonal candlepower of a lamp is the average candlepower of a lamp over the given zone. It is equal to the total luminous flux emitted by the lamp in that zone divided by the solid angle of the zone.

65. Spherical reduction factor of a lamp is the ratio of the mean spherical to the mean horizontal candlepower of the lamp.⁶

66. Photometric tests in which the results are stated in candlepower should be made at such a distance from the source of light that the latter may be regarded as practically a point. Where tests are made in the measurement of lamps with reflectors, or other accessories, at distances such that the inverse square law does not apply, the results should always be given as "apparent candlepower" at the distance employed, which distance should always be specifically stated.

67. Photometric Units and Abbreviations.

Photometric quantity	Name of unit	Symbols and defining equations	Abbreviation for name of unit
1. Luminous flux	Lumen	Φ, Ψ	1.
2. Luminous intensity	{ Candle	$I = \frac{d\Phi}{d\omega}, \Gamma = \frac{d\Psi}{d\omega}$	cp.
3. Illumination	{ Phot, foot-candle, lux	$E = \frac{d\Phi}{dS} = \frac{I}{r^2} \cos \theta.$	ph. fc.
4. Exposure	{ Phot-second Micro phot-second	$E t$	phs. μ phs.
5. Brightness	{ Apparent candle per sq. cm. Apparent candle per sq. in. Lambert	$b_s = \frac{dI}{dS \cos \theta}$ $b_F = \frac{d\Phi}{dS}$	— L. mL.
6. Reflection factor	—	ρ	—
7. Absorption factor	—	a	—
8. Transmission factor	—	τ	—
9. Mean spherical candlepower		scp.	
10. Mean lower hemispherical candlepower		lcp.	
11. Mean upper hemispherical candlepower		ucp.	
12. Mean zonal candlepower		zcp.	
13. Mean horizontal candlepower		mhc.	

⁶ In the case of a uniform point-source, this factor would be unity, and for a straight cylindrical filament obeying the cosine law it would be $\pi/4$.

14. 1 lumen is emitted by 0.07958 spherical candlepower.
15. 1 spherical candlepower emits 12.57 lumens.
16. 1 lux = 1 lumen incident per square meter = 0.0001 phot = 0.1 milliphot.
17. 1 phot = 1 lumen incident per square centimeter = 10,000 lux = 1,000 milliphots = 1,000,000 microphots.
18. 1 milliphot = 0.001 phot = 0.929 foot-candle.
19. 1 foot-candle = 1 lumen incident per square foot = 1.076 milliphots = 10.76 lux.
20. 1 lambert = 1 lumen emitted per square centimeter of a perfectly diffusing surface.
21. 1 millilambert = 0.001 lambert.
22. 1 lumen, emitted, per square foot* = 1.076 millilamberts.
23. 1 millilambert = 0.929 lumen, emitted, per square foot.*
24. 1 lambert = 0.3183 candle per square centimeter = 2.054 candles per square inch.
25. 1 candle per square centimeter = 3.1416 lamberts.
26. 1 candle per square inch = 0.487 lambert = 487 millilamberts.

68. Symbols.—In view of the fact that the symbols heretofore proposed by this committee conflict in some cases with symbols adopted for electric units by the International Electrotechnical Commission, it is proposed that where the possibility of any confusion exists in the use of electrical and photometrical symbols, an alternative system of symbols for photometrical quantities should be employed. These should be derived exclusively from the Greek alphabet, for instance:

Luminous intensity.....	Γ
Luminous flux.....	Ψ
Illumination.....	β .

N **69. Mechanical Equivalent of Light.**—As a standard value for the mechanical equivalent of light, the figure 0.0015 watt per lumen is recommended.

N **70. Visibility.**—The following values for visibility and for relative visibility (maximum visibility being taken as unity) are recommended:

* Perfect diffusion assumed.

Wave length ($\mu\mu$)	Visibility of radiation, average normal eye	
	Relative to that at 556 $\mu\mu$	Absolute (Lumens per watt)
400	0.0004	0.3
10 .....	.0012	0.8
20 .....	.0040	2.7
30 .....	.0116	7.7
40 .....	.023	15.
450	0.038	25.
60 .....	.060	40.
70 .....	.091	61.
80 .....	.139	93.
90 .....	.208	139.
500	0.323	215.
10 .....	.484	323.
20 .....	.670	447.
30 .....	.836	557.
40 .....	.942	628.
550	0.993	662.
60 .....	.996	664.
70 .....	.952	635.
80 .....	.870	580.
90 .....	.757	505.
600	0.631	421.
10 .....	.503	335.
20 .....	.380	253.
30 .....	.262	175.
40 .....	.170	113.
650	0.103	69.
60 .....	.059	39.
70 .....	.030	20.
80 .....	.016	10.7
90 .....	.0081	5.4
700	0.0041	2.7
10 .....	.0021	1.4
20 .....	.0010	0.67
30 .....	.00052	0.35
40 .....	.00025	0.17
750	0.00012	0.08
60 .....	.00006	0.04

REPORT OF COMMITTEE ON LIGHTING
LEGISLATION.*

BY L. B. MARKS, CHAIRMAN.

The duties of this committee as outlined in the TRANSACTIONS of the Society, are to prepare digests of laws on illumination, prepare codes of lighting in special fields and co-operate with other bodies in promoting wise legislation on illumination.

During the past year the work of the committee has been directed chiefly to the following:

Pennsylvania and New Jersey Codes of Lighting Factories, Mills and Other Work Places.—These codes were revised early in the year to conform with the revised code of the Illuminating Engineering Society, with special reference to the requirements of intensity of light on the work. At the time of this revision, the suggestion was made by the Department of Labor that the factory inspectors in these states would welcome any additional technical information that would aid them in enforcing the code. Acting on this suggestion, a course of lectures on the code requirements was given in Philadelphia by Professor C. E. Clewell of the Committee, under the joint auspices of the Pennsylvania and New Jersey Departments of Labor and the University of Pennsylvania. In these lectures the use of the foot-candle meter was demonstrated. Arrangements have since been made for carrying out this plan of lectures and demonstrations in other states.

New York Industrial Lighting Code.—After deliberations extending over the period of a year, the New York State Code of Lighting Factories and Mercantile Establishments was adopted and became effective July 1, 1918. In general, the provisions follow closely those of the Illuminating Engineering Society code, the chief differences being as follows: The New York State code specifies a minimum of 1.00 foot-candle (instead of 1.25 foot-candles) for rough manufacturing operations and includes an additional sub-division of 0.50 foot-candle for work not requiring discrimination of detail; it specifies a minimum height of 20 ft. for unshaded lamps except where such lamps are used for a temporary decorative purpose; it specifies a minimum of 0.25 foot-

* Report presented at the 12th Annual Convention of the Illuminating Engineering Society, New York, N. Y., October 10, 1918.

candle for emergency lighting. The foregoing requirements are mandatory. In an appendix to the code is given a table of minimum intensities proposed for several hundred industrial operations and processes; this classification is tentative, but the Industrial Commission proposes to make these intensity requirements mandatory on July 1, 1919, if after public hearing and a year's experience these values are found to be adequate and just.

Ohio Industrial Lighting Code.—Owing to the illness of the Chairman of the Lighting Code Committee of the Industrial Commission of Ohio, there has been a protracted delay in the completion of this code. Several public hearings have been held and according to latest advices, substantial agreement has now been reached as to the provisions of the proposed code.

Wisconsin Industrial Lighting Code.—This code in its original form did not contain any specification as to intensity of illumination on the work. The code was revised in 1918 and now contains requirements both for natural and artificial illumination intensities. The requirements for artificial lighting follow closely those laid down in the Illuminating Engineering Society code. Two new "general orders" of special significance have been included, as follows:

Lamps suspended at elevations above eye level less than one-quarter their distance from any position at which work is performed, must be shaded in such a manner that the intensity of the brightest square inch of visible light source shall not exceed 75 candlepower.

Exception: Lamps suspended at greater elevations than 20 ft. above the floor, are not subject to this requirement.

Lamps for local lighting must be shaded in such manner that the intensity of the brightest square inch presented to view from any position at which work is performed, shall not exceed 3 candlepower.

The Industrial Commission proposed to try out these regulations and to modify them as experience may dictate.

Insurance Rating Schedule in Factory Lighting.—Conferences were held with insurance companies and with the Workmen's Compensation Bureau, looking to the establishment of standards for factory lighting in the rating schedule. Up to the present time, the intensity of illumination on the work has not been

accepted by the insurance underwriters as a basis for rating factory lighting installations. The Sub-Committee in charge of this matter made the following recommendation:

The foot-candle method for establishing factory illumination standards should be used, making readings with a foot-candle meter or similar device; $\frac{1}{4}$ foot-candle intensity, 30 in. from the floor should be designated as a minimum standard for accident prevention lighting in aisles, passageways, stairways and other open parts about a shop where employees are obliged to travel.

It is pointed out by the sub-committee that exception should be made in certain industries, such as founding and in buildings having dark floors and walls where $\frac{1}{4}$ foot-candle is too low; a higher intensity up to 1 foot-candle is desirable in such cases.

Safety Codes.—The Committee co-operated with the American Museum of Safety, the U. S. Employees Compensation Commission and the Bureau of Standards in connection with a safety code subsequently prepared by the Bureau of Standards, for the safety engineers of Federal arsenals and navy yards. The lighting provisions of this code, which was recently issued, are based upon those in the revised factory lighting code of the Illuminating Engineering Society.

Further co-operation with the Bureau of Standards is now in progress in connection with the National Electrical Safety Code requirements for the illumination of subways, switchboard rooms, power stations and sub-stations, storage battery rooms, and other places where electrical equipment is operated.

Headlighting Legislation.—A digest of existing laws and ordinances relating to headlighting in the different states and in several municipalities has been prepared. Conferences have been held with legislators and others in connection with the revision of present laws and the enactment of new laws relating to headlighting.

The New York State highway law in relation to lights on motor vehicles was amended in May, 1918. The specifications upon which the amendments were based were prepared by the Committee on Automobile Headlighting Specifications of which Dr. C. H. Sharp is Chairman. These specifications and amendments will be reported elsewhere in the TRANSACTIONS. It is believed that the adoption of the provisos as given in the amended

law will result in the amelioration of conditions in three ways: first, by forbidding undue or dangerous glare resulting from the misuse of otherwise acceptable equipment; second, by condemning equipments which produce a glare that is greater than should in any case be tolerated; third, by setting up a numerical standard according to which the acceptability of headlight devices under the law can be determined by photometric tests.

The specifications for headlight tests were issued by the Secretary of State on June 25, 1918. Copies of the amended law and of the specifications for tests may be obtained upon application to the office of the Secretary of State, Albany.

Early in the year the services of the committee were offered to the United States Railway Administration and to the Interstate Commerce Commission, in connection with the possible revision of the regulations relating to railway vehicle headlamps. The sub-committee having this matter in charge has submitted a report of progress.

Code of Lighting School Buildings.—The Code of Lighting School Buildings was completed and published in the TRANSACTIONS (Vol. XIII, No. 3) in April, 1918. This code is issued by the Society in separate pamphlet form. Copies have been placed in the hands of state and municipal authorities interested in the lighting of school buildings.

Co-operation with Other Committees.—The co-operation and assistance of the School Lighting Committee, the Committee on Automobile Headlighting Specifications, and of other technical committees of the Society, and in particular, the valuable services of the President, are gratefully acknowledged.

The appended list of sub-committees undertook the work in special fields as indicated.

Sub-Committees:

Wisconsin Code: Ward Harrison, Chairman.

Insurance Rating Schedule: R. E. Simpson, Chairman.

National Electrical Safety Code: Clarence L. Law, Chairman.

Railway Vehicle Headlamps: M. Luckiesh, Chairman.

Pennsylvania and New Jersey Codes: Messrs. C. E. Clewell and R. ff. Pierce.

Respectfully submitted, For the Committee,

L. B. MARKS, *Chairman.*

STATEMENT CONCERNING THE WORK OF THE
DIVISIONAL COMMITTEE ON LIGHTING—
COUNCIL OF NATIONAL DEFENSE.*

The Divisional Committee on Lighting was created by the Committee on Labor (including Conservation and Welfare of Workers) of the Advisory Commission of the Council of National Defense. The members of the lighting committee were nominated by the Illuminating Engineering Society and appointed by Mr. Samuel Gompers, Chairman of the Committee on Labor.

The scope of the work of the lighting committee, as set forth by the Committee on Labor, is to assist in maintaining and improving the working and living conditions of industrial and public employees from the standpoint of lighting. To this end the lighting committee, shortly after its appointment last year, submitted to the Committee on Labor a Code of Lighting for Factories, Mills and Other Work Places, abstracted from the revised code of the Illuminating Engineering Society. This code was accompanied by a prefatory note setting forth the advantages of maintaining high standards of lighting in industrial establishments. The first edition of this code was printed and published by the Committee on Labor, Washington, in April, 1918. Copies of this pamphlet have been placed in the hands of the labor and industrial commissioners of the various states with a view to ultimately putting the code into operation in every state in the union.

To carry out this program most expeditiously, a representative of the Divisional Committee on Lighting was selected for each state. Appointments of state representatives have been made for thirty-five states, the list of which is appended. Other appointments have been delayed pending the return of Chairman Gompers from Europe.

The proposal to introduce this code has met with favor in most of the states, and in several the legislative enactment of the code is now under consideration; as a rule, however, the state industrial boards have been reluctant to advocate legislative enactment until the rules have been tried out in practice for a longer period

* Statement presented before the 12th Annual Convention of the Illuminating Engineering Society, New York, N. Y., October 10, 1918.

of time. The experience of Pennsylvania, New Jersey, Wisconsin and New York, where industrial lighting codes are in force, will serve as a guide to other states.

The state representatives have conducted a local campaign of education as to the need of the code and have co-operated directly with the commissioners of labor and industry in their respective states. The code has been circularized among manufacturers, and in some states illustrated lectures have been given to more fully elucidate the principles upon which the code is based. The rules of the code have been published in many technical and trade publications throughout the country. The members of the committee have also co-operated with the Committee on War Service of the Illuminating Engineering Society in effectively distributing the pamphlets on protective lighting. In this way the propaganda of good lighting has been spread far and wide and the way has been paved for the adoption of some form of lighting code where heretofore the matter had not been given serious thought.

The work of the Divisional Committee on Lighting has been an amplification of the work of the I. E. S. Committee on Lighting Legislation, carried out under Government auspices. The immediate responsibility for carrying out the plans of the Committee is vested in an executive committee whose names are appended.

Plans are now under way to issue a second edition of the code in which a set of illustrations specially prepared for the purpose will be included.

For the Divisional Committee on Lighting,

L. B. MARKS, *Chairman*,
C. E. CLEWELL,
A. S. MCALLISTER,
PRESTON S. MILLAR,
WM. J. SERRILL,
G. H. STICKNEY.

INTERNATIONAL COMMISSION ON ILLUMINATION.

STATEMENT ON BEHALF OF U. S. NATIONAL COMMITTEE*BY EDW. P. HYDE, PRESIDENT.

It is significant, I think, to refer at this time to the article in the statutes of the International Commission with respect to the objects of the Commission, of which one is "to establish, by suitable means, international understanding on questions of illumination."

It is significant to consider this statement, in view of the fact that those statutes were drawn up at the organization meeting of the International Commission in Berlin in the Fall of 1913, when the stage was all set for the world war. And yet, it is my judgment that the organization of such International Commissions, which have for one of their objects the bringing about of international agreement, is a very potent factor in making impossible such a world war as that in which we now find ourselves. The insane cravings of the war lords of Germany had to be gratified, however, and the International Commission on Illumination was organized, and then ceased its activities. Indeed, the war came so quickly that the Secretary's office in London was not able to get into shape to do business, and whatever international activity there has been, has been of a semi-official nature. Several feelers were put out by the National Committee of the United States, in the hope of keeping open the lines of communication, but those feelers were nothing more than feelers, and practically no result has been accomplished.

It has been thought wise, however, by the National Committee, to keep itself intact. During the days of our neutrality, we had the hope that when the war was over, we would be in a position to take the initiative in the reorganization or the revivifying, I might say, of the International Commission, but since the United States has itself come into the war, I do not know whether that opportunity will be open for us or not. The best we can do, however, is to continue to render those services which we can, to stimulate interest where we can, and to pave the way for pre-

* Statement presented before the 12th Annual Convention of the Illuminating Engineering Society, New York, N. Y., October 10, 1918.

senting material that can be presented at the first technical meeting of the International Commission, should the International Commission reform, which it is our ardent hope that it may do. There are two or three lines of activity in which the United States National Committee has interested itself as activities in which the International Commission would logically be interested. One of them had to do with the standardization of names and units. How far this country has gone is indicated by the report which has just been presented by Dr. Sharp, and I think it is fair to say that we have gone so far beyond any other country, that the report of this committee will furnish at any reasonable time from now, a starting point for future international discussions.

Another matter in which the National Committee was interested was the accumulation of legislative enactments—data regarding legislative enactments in the various countries, and a resolution had already been passed in the National Committee of the United States, to endeavor to secure the compilation of such information. Unfortunately, that activity was discontinued, but I think that it would be a good thing if we in this country should resume it as one in which we are sure the International Commission will be interested when the war is over.

A third activity which the National Committee undertook was the stimulation of research along those lines in which we thought the International Commission would be interested, and though nothing in a very formal way has been accomplished, the committee has been successful in stimulating research, and some excellent results have been obtained.

The International Commission was organized as a result of overtures which were made by the American Gas Institute, with the co-operation and support of other technical societies in this country and abroad, which caused the reorganization of the old International Photometric Commission into the International Commission on Illumination. And let us hope that notwithstanding the fact that we are one of the participants in the war, we may be ready to repeat the effort which we made before, and do our part in bringing about the rebirth of the International Commission on Illumination, which I think should have very important and very valuable functions to perform.

STATEMENT CONCERNING WAR COMMITTEE OF
TECHNICAL SOCIETIES.*

BY CAPT. LLOYD M. SCOTT.

The Committee consists of two representatives from each of the ten largest technical and scientific societies, including the Illuminating Engineering Society, and functions directly with the Army. The Chairman of the Committee has been made a member of the National Research Council and of the Naval Consulting Board; three army officers have been appointed to liaison service with the latter board. Thus, there is formed something like an interlocking directorate, which is equally as effective in military and naval affairs as in business. The present office of this Committee is in Washington, D. C., where it comes in intimate touch with the Inventions Section of the General Staff and thereby all problems likely to be submitted.

The present war has called into service every branch of science from astronomy to zoology, and it is thought that by scientific training, directed into a particular channel, the latent talent, which the Yankee is known to possess, will give startling results.

Although a certain percentage of the plans and inventions submitted are in a class with the "Perpetual Motion" machine, as regards possibility and practicability, many inventions—necessarily kept secret—are being employed at the present time in the prosecution of the war. The General Staff has arranged to let the wants of the Army along lines of invention, some of which are problems of lighting, be known to the scientific men of the country. When solutions are evolved, military technical examiners of the Army War College pass on them and submit them to the departments in need of the particular devices.

Problems naturally fall into three classes:

Those of a confidential nature, which can only be sent to specialists; those of a character which would indicate that they should be sent to specialized groups; those that are of a general nature and about which any man in scientific work may have a flash of genius which will solve them.

The object to be accomplished is to so speed up the scientific inventive genius of the country as to beat the Hun.

* Statement presented before the 12th Annual Convention of the Illuminating Engineering Society, New York, N. Y., October 10, 1918.

ABSTRACT—RESEARCH OF AMERICA.*

BY COLONEL R. A. MILLIKAN.

Colonel Millikan, after outlining various relations of the National Research Council, at Washington, depreciated the prevalence in our newspapers of "Spread Eaglism"—or American Brag. We are doing a great work; we are making important sacrifices, but they are not comparable as yet with those of our Allies. Our total casualties up to the present time are about on a par with Great Britain's list for one week.

ILLUMINATING ENGINEERING SOCIETY REPORT ON
AVIATION FIELD LIGHTING.

In accordance with the usual practice the report was not adopted as a whole, but was made available to the officers of the Signal Corps so that such parts as met their immediate needs could be applied.

As it was deemed expedient to train aviators under mobile conditions, such as they would encounter abroad, no permanent fields were being established. Parts of the report which applied to a permanent field were therefore not used. The plans for building illumination, on the other hand, were immediately applied.

FUNCTIONS OF THE NATIONAL RESEARCH COUNCIL.

The National Research Council is a clearing house for research activity and a stimulator of new activities. It does not plan to do research work itself, but, rather, to get research done through the utilization of existing agencies or through the creation, if need be, of new agencies. It does not strive to retain control of such agencies when created. Its business is to start things. Thus, it started the Sound Ranging Service, which is now under control of the Engineer Corps. It was responsible for the creation of the Science and Research Division of the Signal Corps, which is now independent of the Research Council. It assisted largely in initiating the anti-submarine work of the Navy, but the control of that work is in the hands of the Navy. Its work is, and forever should be, that of the pioneer who is eternally blazing

* Address presented before the evening session of the 12th Annual Convention of the Illuminating Engineering Society, Hotel McAlpin, New York, N. Y., October 10, 1918.

the trail, but leaving to other hands the cultivation of the regions already won.

A second function is to act as a co-ordinating agency between army, navy and civilian research bodies. In its war work, the United States is the only one of the major belligerents which has not a central Board of Inventions and Research. Its war research is carried on under every bureau of the Army and Navy, the National Research Council acting as the one link to bind them all together, and to connect the representatives of all these bureaus with the various committees of civilian bodies, such as the Committee of the Illuminating Engineering Society, so as to make available the suggestions that such committees may have.

AMERICAN CONTRIBUTIONS TO WAR SCIENCE.

With regard to the contribution to science of the nations at war, it should be noted that with over twice as many people as Great Britain, we have not an equal number of scientists of first calibre. Our populace in general does not appreciate science on the scale of our European competitors. We are not really interested in, nor do we show appreciation of science and its place in human history. With many more available men, the United States is not comparable either to Great Britain or to France in the number or importance of its research contributions to the war. Nevertheless, we are doing much good work and some of it is of first importance.

RESEARCH AFTER THE WAR.

With our form of government and our intense individualism, it is more difficult than it is in an autocracy like Germany to make the whole country pull together and subordinate its individualistic tendencies to a common end. Nevertheless, some of our recent accomplishments give us ground for the greatest satisfaction and the greatest hope. For example, our handling of the liquor problem, of conscription, of fuel saving.

Competition following the war will be pitiless. The nation that fails to apply advanced scientific knowledge in boundless measure will be hopelessly handicapped. The United States must not lag behind in research work. The next few years should see a mighty advance along this line. It will require organization.

It will require, above all, the development of research men. This will necessitate the development of some new types of research institutions, and above all we must find means to induce men to enter the scientific field. Great Britain, for instance, has made a magnificent investment in the form of scholarships. Such a procedure is vitally necessary to the commercial life of the United States, if she is to maintain a leading place among the nations.

ABSTRACT—LIGHTING AND THE WAR PROGRAM.*

BY O. MONNETT OF THE U. S. FUEL ADMINISTRATION.

In his introduction, Mr. Monnett explained the necessity for the restrictions of the Fuel Administration. Many people not understanding the reason for these rules, have questioned their desirability. The country, as a whole, however, has shown a wonderful spirit of co-operation.

In the last analysis this war, whether considered from the viewpoint of ships, shells, machinery or industry, is based on coal—on the coal supply. Coal is necessary to manufacture the shell and to manufacture the gun to fire it. At Verdun alone, the French fired over 60,000,000 shells—a total tonnage of 1,800,000 tons of steel. To make one ton of steel in the form of shells requires 5 tons of coal. Coal is necessary to build the ship—and to run the ship after it has left the ways. A 3,000-ton transport takes 8,000 tons of coal in the building. From then on its demand for coal is continuous.

The production of war munitions depends directly upon the rate of production and rapidity of transportation of coal. We are producing more coal now than ever before—and with a smaller army of miners. Out of 720,000 miners, 60,000 have been taken by the draft, while many others have been drawn to the war industries. In spite of this our last year's coal production increased 10 per cent. All other warring nations have shown a decrease in their coal supply. We are keeping the miner at his job and are making him realize the importance of his role. The miner himself is a man who is hard to control, that is, he wants to enlist; the attitude of the Fuel Administration to-day is that every miner is as important in his work as the man in the front line trenches.

The extent of the coal industry is hard to realize. One-third of all tonnage moved is coal; it cannot be taken care of in a few days; it is an entire year's job. Transportation, with the loss of serviceable men in the draft and the additional tonnage needed by war munitions, is another big proposition. At the maximum

* Address presented before the evening session of the 12th Annual Convention of the Illuminating Engineering Society, Hotel McAlpin, New York, N. Y., October 10, 1918.

rate of production and transportation, we will mine 700,000,000 tons of coal this year—which amount, mammoth as it is, will be short 50,000,000 tons. To reduce that shortage, we are cutting out all leaks—all dissipation of energy. It is said that the illuminating industry takes 12,000,000 tons of coal per year. Even a 3 per cent. saving is a mighty step in conservation. It would save enough coal to fight a battle like the St. Mihiel. The psychological effect of this saving is even of greater importance. A blaze of light creates the impression that things are all right after all. This is not the idea we desire. We want the strength of purpose that holds that nothing is all right until the Hun has received his knockout blow.

ABSTRACT—THE AUTOMOBILE HEADLIGHT.*

BY ARTHUR H. FORD.

The illumination produced by a point light source in a parabolic mirror is briefly discussed, with regard to the effect of moving the light source away from the focus.

This is followed by a calculation of the necessary relative beam intensity, at different angles from the axis of the reflector, required to give a uniform illumination intensity, normal to the beam, at various places on a road 30 ft. wide; the axis of the reflector being parallel to the center of the road and just above it. This calculation shows that the lines of equal beam intensity should be horizontal and that the beam intensity should increase as the angular distance from the axis just below the lamp decreases. The width of the road lighted at various distances by a beam of given spread is also calculated. These calculations give a means of comparing the shape of the lighted field produced on a screen normal to the axis of the reflector with the illumination to be expected on the road surface.

Various means for producing the desired shape of lighted field are then discussed. One method for producing this result is the use of a straight horizontal filament with axis at right angles to the axis of the reflector and just above the focus. A helical filament having its axis coincident with the focus of the reflector will produce essentially the desired street illumination, but will throw more than half the light above the axis of the headlight, where it is not needed, and where it is particularly objectionable because of the blinding effect on drivers of passing vehicles. These defects can be overcome by the use of prismatic fronts on the headlights. Such fronts must be carefully designed and the lamps properly adjusted if the desired effect is to be produced. Screen illumination produced by lamps having various filament shapes and used with various types of prismatic and lenticular headlight fronts are shown.

* Paper presented before the Chicago Section of the Illuminating Engineering Society, Chicago, Ill., December 15, 1917.

ANNUAL REPORT OF THE COUNCIL FOR 1917-1918.*

BY THE GENERAL SECRETARY.

The past year of the Society's endeavors, the twelfth since its inception, has been marked with achievements and success notwithstanding the unusual trying conditions brought about by circumstances due to the war. At no time, do the past records show, have we been called upon for so many activities, or have such opportunities to broaden our usefulness been presented. It is, therefore, with a feeling of satisfaction that we can look back upon a year of such accomplishments.

COUNCIL.

The Council of the Society during the past fiscal year held nine consecutive regular monthly meetings, and was represented during three summer months, July, August and September, by the Council Executive Committee, which transacted the affairs of the Society during that period. The attendance at the meetings was all that could be hoped for considering the national emergency and stress of business to which all have been subjected recently. The supervision of the affairs of the Society was carried on with the same degree of earnestness that has always been characteristic of your officers.

MEMBERSHIP.

The membership of the Society during the 1917-18 fiscal year shows some changes, and at the expiration of the period the statistics show a net loss of 37 members, or 3 per cent. of the total at the beginning of the year. Your Membership Committee has done excellent work in distributing propaganda, endeavoring to secure new members, and their results have been successful although the number of new members secured did not balance those that resigned or were dropped. The number of sustaining members has increased slightly. The following table gives the membership statistics for the year according to Sections, divided into members and associate members.

* Report presented at the 12th Annual Convention of the Illuminating Engineering Society, New York, N. Y., October 10, 1918.

	Chicago		New England		New York		Philadelphia		Pittsburgh		Non-Sec.		Total		Total
	M	A	M	A	M	A	M	A	M	A	M	A	M	A	
October 1, 1917.....	35	131	26	70	138	286	65	237	42	71	40	117	346	912	1,258
Elected	2	5	1	22	6	21	5	34	1	4	3	27	—	—	131
Transfers	3	—	1	—	5	—	4	—	1	—	5	—	—	—	19
Reinstatements	2	3	1	—	2	2	2	3	1	1	—	2	—	—	19
Transfers	—	3	—	1	—	5	—	4	—	1	—	5	—	—	19
Resignations	3	17	2	10	6	22	4	24	4	10	5	7	—	—	114
Deceased	—	2	—	1	—	3	—	3	—	—	—	1	—	—	10
Dropped	3	14	1	6	2	10	—	10	1	5	4	7	—	—	63
Total Sept. 30, 1918.....	35	103	26	74	143	269	72	233	40	60	39	126	356	865	1,221

Our members in military service, numbering approximately 100, are carried on the membership roll during the period of the war without payment of dues, and in cases where these members requested it, their dues for the past year have been refunded to them.

FINANCES.

At the beginning of the administration a budget was prepared, as is usually the custom, showing the income and expenses anticipated for the year, and as the prospect for a growth in membership was bright, meaning additional revenue, a liberal allowance was made for both receipts and expenditures. As the year progressed, however, it became evident that the prophesies were not correct and as a result of the changes, and in consequence of reduced revenue, the new condition of affairs was presented to the Council early in the year. Certain committees and the General Office were asked to make earnest endeavors to minimize and curtail expenses as much as possible. All entered into the spirit of co-operation and as a result of these efforts, without affecting whatever the benefits to the membership, the condition of the finances at the expiration of the year shows a safe balance. The annual report of the auditors is appended.

SECTION DEVELOPMENT.

The section work for the year taken altogether shows somewhat of a decline in the activities. This is undoubtedly due to conditions governed by local circumstances. The attendance at meetings has fallen off as compared with the year previous. The number of papers presented was slightly less, and the number of meetings held were fewer. This situation should not be construed as indicating any lack of interest on the part of the membership, but rather a reflection upon our activities that should be expected.

There has been some discussion as to the advisability of changing the period between meetings, making the intervals longer than a month. This was brought about by the fact that two Sections experienced difficulty in securing an attendance of sufficient size to warrant the expense involved in holding a meeting. Whether or not any change is advisable during the war period depends upon the feeling of the local boards. It is a question,

however, that should merit the serious consideration of the incoming administration.

The situation regarding the Pittsburgh Section has been rather alarming, and the present administration closes with a local Board of Managers divided among themselves as to whether or not the Section should be continued. During the past year two meetings have been held, one in Cleveland and one in Pittsburgh. Both were well attended, the former being an all-day session. An extract from the local Secretary's report is of interest: "It is evident, however, from an analysis of the members in the Pittsburgh District that a very high percentage are not available for the work of the organization in promoting meetings and keeping up attendance and discussions. Such of those as are in Pittsburgh or the near vicinity are in most cases engaged in other lines of engineering work, in which illumination is not of first importance, as compared with some of their other interests. The Section has also suffered severely from changes in the personnel in this vicinity. In consequence of this condition, it was impossible to promote additional meetings or in fact to carry on any meetings in Pittsburgh, except one of essentially war interest, which would be of vital help to manufacturers. For this reason, it is believed by the Board of Managers of the Section that further meetings of the Pittsburgh Section on a regular schedule should be postponed until conditions are more favorable." The desirability of eliminating the Section or changing its location to some other city where the interest of the membership may be more pronounced, should be considered at an early date.

At the beginning of the administration the New England Section activities showed evidence of decline because of the absence of the officers of the local Section. It is a pleasure to report, however, that the new management has shown every indication of re-establishing conditions to a normal basis. The following data regarding Sections is of interest.

	Pittsburgh	Phila.	New York	New Eng.	Chicago
Number of meetings	2	8	8	1	9
Number of papers...	7	9	8	1	9
Expenses	\$181.72	\$367.12	\$474.08	\$109.15	\$326.52
Members	100	303	474	94	326
Cost per member for Section expense...	\$1.81	\$1.21	\$1.13	\$1.16	\$2.38

New local representatives have been appointed during the year,

making a total of 37. Much interest has been manifested by these members, there having been arranged several meetings under their auspices in well distributed locations throughout the country. In addition to representatives in this country, there are local representatives now in South Africa and Canada.

The TRANSACTIONS of the Society have been published regularly, consisting of nine numbers, and incorporating the following material:

Number of papers with discussion.....	33
Number of abstracts	4
Number of pages of Society notes.....	111
Number of paid advertisements.....	113
Number of pages of advertisements.....	72

The Papers Committee reports that the distribution of the year's technical papers among Sections and before the Society at large was as follows:

Correspondence Convention	25
Presented before Chicago Section.....	9
Presented before Philadelphia Section.....	9
Presented before Pittsburgh Section.....	7
Presented before New York Section.....	8
Presented before New England Section.....	1
Presented before Society at large.....	1

In addition to this there were other papers presented before the Sections which did not appear in the TRANSACTIONS.

GENERAL OFFICE.

During the past year several changes have been made in the personnel of the General Office staff. Your former Assistant Secretary has resigned to engage in war work. It was deemed advisable to appoint in his place Miss Ruth A. Fischel, who has been an office assistant in the General Office for the past three years. The appointment of a woman as Assistant Secretary is unusual, but under the circumstances and as a war measure, it was thought advisable to make such a decision, thereby releasing a man for other duties in connection with the prosecution of the war. This action was taken after considerable deliberation, and we were fortunate in having on the office staff a woman who has given all indications of making a very successful Assistant Secretary.

The principal work of the General Office during the past year has been in connection with the editing and publication of the TRANSACTIONS, correspondence with the membership, preparation and furnishing of data necessary to the activities of the various committees, the handling of all finances, and bookkeeping. Considerable work has also been done incidental to the successful operation of the Sections. Owing to the unavailability of the Chairman of the Editing and Publication Committee during the latter part of the administration's fiscal year, all of the work involved under this committee's jurisdiction, which is the supervision of the editing and publication of the TRANSACTIONS and the work incidental thereto, was handled by the General Office.

COMMITTEES.

During the past year there were 22 committees appointed by the President and the Council. The work of these various committees for the past year has been very commendable. An unselfish devotion evidenced by their attendance at meetings or attention to details of correspondence has been displayed. Under the leadership of carefully selected, experienced and well-informed chairmen, the work has progressed with satisfaction and recognition. Notably among the committees that have accomplished results are the Lighting Legislation and War Service Committees. The success and accomplishments have been due in a large measure to the energetic leadership of their chairmen, and the recognition attained through the various State and Federal governmental authorities through the instrumentality of the representatives of these committees should be a further incentive to extend all our resources, scientific, educational and financial, toward the promotion of our ideals.

APPENDIX.

October 7, 1918.

ILLUMINATING ENGINEERING SOCIETY,
29 W. 39th St., New York.

GENTLEMEN:

In accordance with your instructions we have examined the books and accounts of the Illuminating Engineering Society for the twelve (12) months ended September 30, 1918.

The results of this examination are set forth in two exhibits, attached hereto, as follows:

Exhibit "A"—Balance Sheet, September 30, 1918.

Exhibit "B"—Earnings and Expenses, for the twelve months ended September 30, 1918.

We certify that, in our opinion, the Balance Sheet is correct, that the statement of Earnings and Expenses properly sets forth the results of the operations for the twelve months ended September 30, 1918, and that both are in agreement with the books.

Respectfully submitted,

WM. J. STRUSS & Co.,
Certified Public Accountants.

BALANCE SHEET, SEPTEMBER 30, 1918.

EXHIBIT "A."

Assets.

Cash on hand and in bank.....	\$ 2,540.13
Liberty Bonds	2,000.00
Accounts Receivable:	
Advertising	\$ 71.61
Sustaining Members dues	180.00
Associate Members dues	40.00
Fees	15.00
Transactions	11.95
Miscellaneous	12.00
	<hr/> 330.56
Furniture and fixtures	713.95
	<hr/> \$ 5,584.64

Liabilities.

Advance dues	\$ 103.50
Advance fees	7.50
Reserve for unrepresented items.....	350.00
Surplus:	
September 30, 1917	\$3,766.42
Adjustments prior period	136.23
	<hr/> \$3,902.65
Net profit for the twelve months ended Sep- tember 30, 1918	1,220.99
	<hr/>
Surplus September 30, 1918.....	5,123.64
	<hr/> \$ 5,584.64

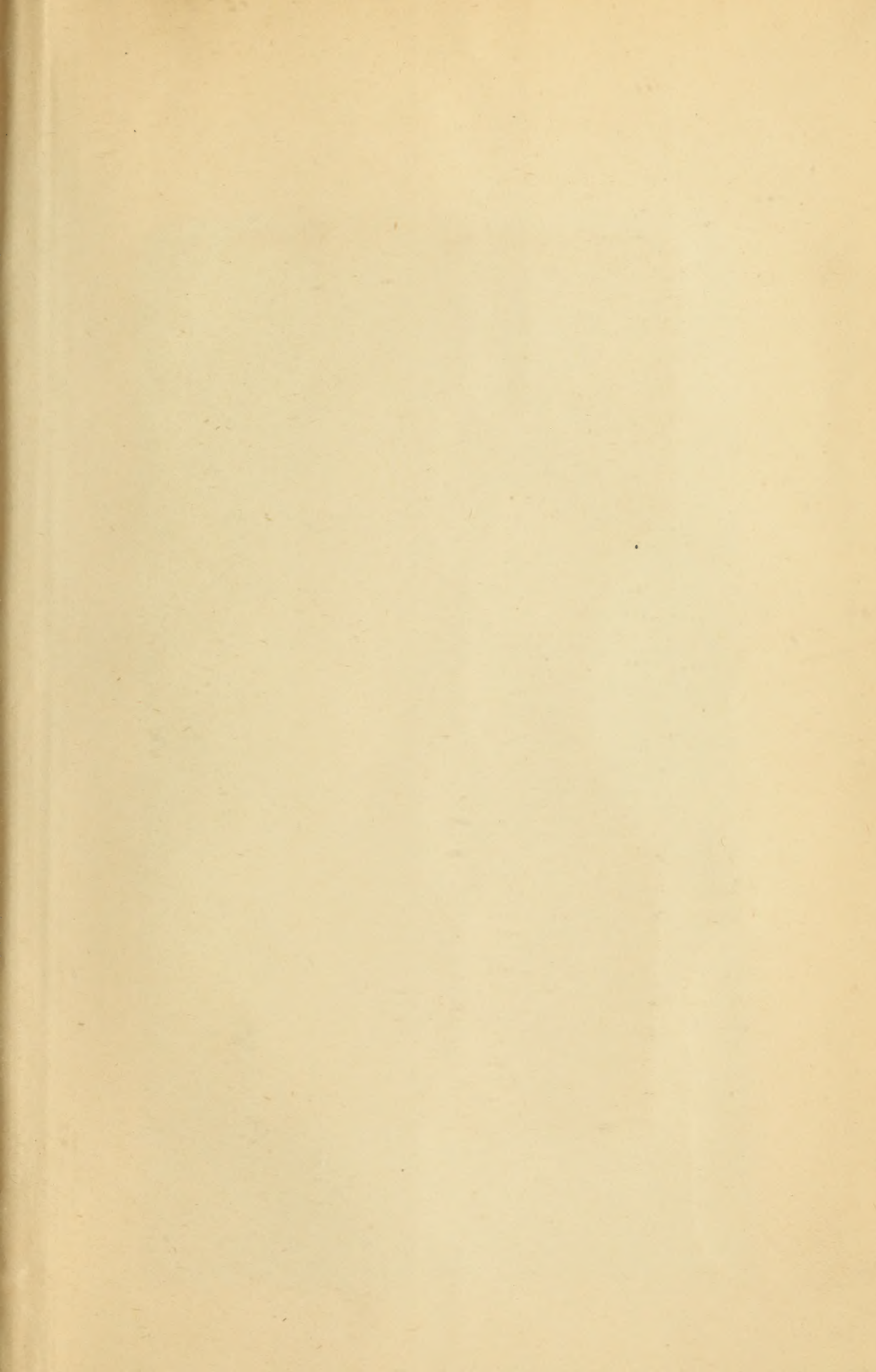
STATEMENT OF EARNINGS AND EXPENSES FOR THE TWELVE MONTHS
ENDED SEPTEMBER 30, 1918.
EXHIBIT "B."

Earnings.

Members dues	\$3,287.19	
Associate Members dues	4,092.50	
Sustaining Members dues	3,985.00	
Initiation fees	285.00	
Advertising sales	966.12	
Transactions	628.21	
Miscellaneous sales	438.13	
Interest earned	95.56	
Back dues and fees.....	69.92	
		<hr/>
Total		\$13,847.63

Expenses.

Transactions	\$3,254.31	
General Office:		
Salaries	\$3,012.55	
Rent	1,221.56	
Printing and stationery	1,012.27	
Postage	248.78	
Telephone	163.06	
Miscellaneous	337.97	5,996.19
		<hr/>
New York Section	474.08	
Philadelphia Section	367.12	
Chicago Section	326.52	
Pittsburgh Section	181.72	
New England Section	109.15	
Committee expense	172.58	
Convention expense	603.93	
Miscellaneous expense	1,061.72	
Depreciation furniture and fixtures.....	79.32	
		<hr/>
Total		\$12,626.64
		<hr/>
Excess of Earnings over Expenses.....		\$ 1,220.99



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Illuminating engineering

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Engineering

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